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THE

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The Mineralogical Society.

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THE MINERALOGICAL SOCIETY

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 20, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

The resignation of Mr. Herbert Stanley Jevons, Ordinary Member, and the death of Professor Vivant Léon Moissenet, Honorary Member, on February 2, 1906, were announced.

Mr. B. Kitto and Mr. J. P. De Castro were appointed auditors of the accounts for the year ending December 31, 1905.

Mr. L. J. Spencer reported that he had forwarded, on behalf of the Society, 539 slips relative to mineralogical and crystallographical papers and books, published in the United Kingdom during 1905, to the Central Bureau of the International Catalogue of Scientific Literature.

Resolved that a Council Meeting be held thirty minutes before each Ordinary Meeting, and be announced on the date-card of meetings for the year.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 20, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Twenty-four Members and one Visitor were present.

The following papers were read:—

1. On the occurrence of Caledonite and Linarite in County Wicklow: by Mr. Arthur Russell.

2. On the parallel growth of salts on minerals: by Mr. T. V. Barker.

In addition to specimens shown by authors in illustration of their papers, the following specimens were exhibited: by Dr. J. W. Evans, twin-crystals of Thorianite; by Mr. F. N. A. Fleischmann, various Zeolites; by Mr. L. Fletcher, a Brazilian Euclase and Japanese Chalcopyrite and Danburite; by Mr. A. Hutchinson, a remarkable crystal of Calcite from Kimberley, South Africa; by Mr. Arthur Russell, crystals of Brookite recently collected by him at Tremadoc.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 12, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

An application from the Imperial Institute, London, for exchange of publication was approved.

Resolved to nominate Professor W. W. Watts as Foreign Secretary, in place of Professor J. W. Judd retiring, and Mr. J. J. Beringer, Mr. Harold Hartley, Dr. G. T. Prior, Dr. A. P. Young in place of the four retiring Members of Council (Messrs. H. L. Bowman, H. F. Collins, C. G. Cullis and R. H. Solly).

The audited Balance Sheet for the year ending December 31, 1905, was submitted and approved.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 12, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Seventeen Members and one Visitor were present.

The following papers were read:—

1. A pseudomorph of Quartz after Apophyllite from the Val Sumela, Fassathal: by Mr. Harold Hartley and Mr. Noel G. Thomas.

2. A heating-stage for the Dick microscope: by Mr. Harold Hartley.

3. The occurrence of Axinite in the area south of Bodmin in Cornwall: by Mr. George Barrow.

4. Cassiterite pseudomorphs from Bolivia: by Mr. Richard Pearce.

5. Notes on Skiodroms and Isogyres: by Dr. J. W. Evans (p. 230).

6. Crystallography of Sartorite from Binn: by Dr. C. O. Trechmann (p. 212).

In addition to specimens shown by authors in illustration of their papers, the following specimens were exhibited: by Mr. J. P. De Castro, a fine crystal of Tantalite from Western Australia; by Mr. L. Fletcher, two specimens of Cornish elvan, one showing a loose nodule of graphite and the other a loose pebble; by Mr. R. Pearce, Axinite from St. Ives, Cornwall.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 13, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Mr. George Stanfield Blake was elected an Ordinary Member of the Society.

The following were selected as the dates of Meeting for the year 1907 :—Tuesdays, January 29, March 19, June 11, November 12, the last to be the Anniversary Meeting.

The draft annual report of Council, submitted on behalf of the General Secretary, was approved.

The announcement was made of the deaths of Professor Penfield, Honorary Member, and Mr. R. P. Greg, formerly Ordinary Member and Treasurer.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 13, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Twenty-five Members were present.

The election of Mr. G. S. Blake to the Ordinary Membership was confirmed.

The scrutineers reported that thirty-eight voting papers for the election of Officers and Council had been returned, and that the List as nominated by the Council was approved, namely :—

President. Prof. H. A. Miers, M.A., D.Sc., F.R.S.

Vice-Presidents. Prof. W. J. Lewis, M.A., F.C.S.
Prof. G. D. Liveing, M.A., D.Sc., F.R.S.

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Foreign Secretary. Prof. W. W. Watts, M.A., F.R.S.

Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

. W. Evans, LL.B., D.Sc., F.G.S.	F. W. Rudler, I.S.O., F.G.S.
ev. J. M. Gordon, F.G.S.	A. E. H. Tutton, D.Sc., F.R.S.
. A. Howe, B.Sc., F.G.S.	J. J. Beringer, A.R.S.M., F.C.S.
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F. De Castro, M.A., F.C.S.	G. T. Prior, M.A., D.Sc., F.G.S.
S. Flett, M.A., D.Sc., F.R.S.E.	A. P. Young, Ph.D., F.G.S.

The following Annual Report of Council was read :—

The Balance Sheet for the year ending December 31, 1905, shows that the Assets of the Society (exclusive of the Library and the Stock of the

Journal) amounted to £690 3*s.* 5*d.*, and that the Liabilities amounted to £17 2*s.* 10*d.* The number of Life-Members on December 31, 1905, was fifty-one; the value of the Stock invested in the names of the Trustees of the Society was on that date £612 12*s.* 8*d.*, corresponding to £12 0*s.* 3*d.* for each Life-Member.

During the Session 1905–6 the Society has lost one Ordinary Member by resignation (Mr. Jevons), and two Honorary Members by death (Professors Penfield and Moissenet); one Ordinary Member (Mr. Jones) and one Honorary Member (Professor Baumhauer) have been elected. The total number of Members on November 12, 1906, was 123, of these nineteen are Honorary Members and 104 are Ordinary Members; of the latter fifty-one have compounded for their annual subscription.

Four Meetings have been held during the year, all in London, and (by kind permission) in the apartments of the Geological Society, Burlington House.

Only one number of the Journal, No. 65, published in May, 1906, has been issued during the Session. Papers by Professor Miers and Mr. Chevalier dealt with the crystallization of salts from solutions in the metastable and labile conditions; Dr. Evans contributed papers on gnomonic projection, the determination of optic axial angles, and the identity of the amiantos of the ancients with chrysotile; Messrs. Crook and Jones discussed the chemical composition of the ferromagnesian titanates; Dr. Prior described dundasite from Wales; Mr. Herbert Smith discussed a method for the determination of refractive indices, and described a new mineral, paratacamite; Mr. Spencer gave an account of phenacite and other minerals from German East Africa; and Mr. Solly contributed further notes on minerals from the Binnenthal.

The Council has to congratulate the Society on its continued prosperity.

On the motion of Mr. Hutchinson, seconded by Mr. Bowman, the Report was adopted.

Announcement was made of the deaths of Professor Penfield and Mr. R. P. Greg.

The dates of Meeting for the year 1907, proposed by the Council, were approved.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried with acclamation.

The following papers were read:—

1. Growth of crystals of soluble salts on each other: by Mr. T. V. Barker (p. 235).

2. Notes on some Bolivian Minerals: by Mr. L. J. Spencer.

3. Note on Ilmenite from Brazil: by Mr. G. F. Herbert Smith (p. 258).

4. Description of the Lengenbach quarry and of the minerals found there in 1906: by Mr. R. H. Solly.

5. Note on the thirty-two classes of symmetry: by Mr. H. Hilton (p. 261).

Lantern-slides were shown by Mr. Barker in illustration of his paper. Specimens of Monazite from Cornwall and Harmotome from Co. Wicklow were exhibited by Mr. A. Russell; and crystals of Sartorite by Dr. C. O. Trechmann.

MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1905.

Receipts.	£ s. d.	£ s. d.
Balance from 1904		82 13 7
Subscriptions—(1) current	45 3 0	
(2) arrears	2 2 0	
	47 5 0	
Entrance fees		2 2 0
Sale of publications by publishers (1904)	24 12 6	
Do. by G. Savigar (1904)	0 15 4	
	25 7 10	
Dividends on Stock		15 12 0
		£173 0 5

Payments.	£ s. d.	£ s. d.
Printing Magazine (No. 63)	27 16 8	
Authors' separate copies	4 11 0	
Illustrations	4 5 0	
		36 12 8
Printing Magazine (No. 64)	19 1 4	
Authors' separate copies	3 19 6	
Illustrations	2 5 0	
		25 5 10
Miscellaneous Printing		6 12 7
Binding		7 10 0
Editor's Honorarium (1904)		10 10 0
G. Savigar for care of Stock		1 1 0
Postage and Parcels (including postage on Magazine)		4 16 11
Porter's Fee		1 0 0
Bank Charges		0 1 0
Investments		31 7 0
Balance at Bank	45 17 5	
„ in Office	2 6 0	
		48 3 5
		£173 0 5

Examined and compared with the vouchers, and found correct.

(*Signed*) BENEDICT KITTO
J. PAUL DE CASTRO } Auditors.

Liabilities.	£ s. d.
Owing for Editor's Honorarium (1905)	10 10 0
„ Miscellaneous Printing	3 16 0
„ G. Savigar for care of Stock (1905)	1 1 0
„ Do. for postage (1905)	0 4 0
„ Secretary for fee to Porter (advanced)	0 10 0
„ „ „ postage (1905)	0 15 0
„ Treasurer „ „ (1905)	0 6 10
Excess of assets over liabilities	673 0 7

Assets.	£ s. d.	£ s. d.
Balance at Bank		45 17 5
„ in Office		2 6 0
Consols (£680 14*s.* 3*d.*, valued at £90)		612 12 8
Sale of publications—		
Balance owing from Publishers	17 12 6	
„ „ „ G. Savigar	5 8 10	
		23 1 4
Subscriptions in arrear, valued at		6 6 0

THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 66. February, 1907. Vol. XIV.

The optical characters of Antimonite.

By A. Hutchinson, M.A., Ph.D.

Demonstrator of Mineralogy in the University of Cambridge.

[Preliminary note read March 22, 1904.]

In a paper communicated to this Society in March, 1903 [1], it was shown that antimonite is fairly transparent to radiations of long wave-length and that its behaviour between crossed nicols is consistent with orthorhombic symmetry. At the same time it was pointed out that it would be of interest to determine the wave-lengths of the radiations transmitted and the principal indices of refraction of antimonite for these radiations. On undertaking this investigation it was soon found that antimonite was quite sufficiently transparent to the rays at the extreme red end of the visible spectrum to enable visual observations to be made, and in a verbal communication to the Society on March 22, 1904, it was stated that the indices of refraction for red light were 4·129 for rays vibrating parallel to the axis Z and 3·873 for rays vibrating parallel to the axis X. These numbers were based on measurements made on a prism the faces of which were very indifferent. They can therefore only be regarded as rough approximations. Further, the exact wave-length of the radiation transmitted was unknown, an omission of some importance, as a few measurements made with a thermopile in the infra-red indicated that the dispersion in this region was very great. These preliminary results were, however, of sufficient

[1] Min. Mag., vol. xiii, p. 312.

interest to warrant an attempt to carry out a complete determination of the optical constants of antimonite with all the accuracy possible, and this investigation, though not quite finished, has now reached a stage when it seems desirable to put on record the results so far obtained.

The visible radiations transmitted by antimonite.—The first point to be determined was the wave-length of the visible radiations transmitted by antimonite. To effect this, one of Thorp's replicas of a Rowland grating having 14,504 lines to the inch was mounted on a spectrometer. Sunlight reflected from the silver surface of a heliostat mirror was focused on the slit by a quartz lens of 7 cm. diameter and 86 cm. focal length and the telescope was set on the line A of the solar spectrum. The slit was then entirely covered with a very thin cleavage-flake of antimonite. On now looking through the telescope it was found that the A line could still be distinctly seen, but that the more refrangible end of the spectrum was absolutely cut off just beyond A, while a considerable extension of the spectrum towards the infra-red had become visible. The antimonite was thus acting as one of the screens recently described by M. Štefánik[1], which have enabled him to see as far down the infra-red as ρ, σ and τ, and even under favourable circumstances to Φ, wave-length 1135.

On making these observations in a dark room, a faint line was observed in the region below A and by measurement was identified with Z of the infra-red solar spectrum, wave-length 823. The visible spectrum seen under these conditions extends somewhat beyond Z, but the illumination is too faint to permit of the identification of any more lines. It was thus established that a thin plate of antimonite transmits visible radiations extending from about 750 to about 850, and that in this region A and Z can be identified and used as standards.

Indices of refraction.—The principal indices of refraction were determined by the aid of two prisms prepared from a fine crystal of Japanese antimonite by Adam Hilger, Ltd.[2]

Prism I.—This prism was cut with its refracting edge parallel to the long axis, *Z*, of the crystal. One face was parallel to the cleavage-plane *b*(010), the other inclined to it at an angle of 7° 41′. Both faces had a very good polish and were sufficiently plane except quite close to the

[1] Compt. rend. Acad. Sci. Paris, 1905, vol. cxli, p. 585; 1906, cxlii, p. 986; cxliii, pp. 573 and 734.

[2] I desire here to record my appreciation of the great care and skill shown by the firm in working a very troublesome substance.

thin edge. One face gave a sharp reflected image of the slit, that afforded by the other was less satisfactory. When the prism was placed on the spectrometer and sunlight condensed on the slit by the above mentioned lens, two broad red images of the slit were seen in the telescope. These images were plane polarized, the vibrations in the most deviated image being parallel to the refracting edge of the prism, i. e. to the axis Z of the crystal. The lines A and Z could be detected in both spectra, though they were not very distinct. The prism was adjusted so that the cleavage-face was perpendicular to the axis of the collimator. In this position the light is incident perpendicular to a principal plane, and the values of two of the principal indices of refraction can be deduced from the relation $\mu = \frac{\sin (P + D)}{\sin P}$, where P is the angle of the prism and D the deviation observed.

The mean values of the deviations were, for the line A 27° 26′ and 25° 4′ respectively, and for the line Z 26° 25′ and 24° 3′. Whence follow the values :—

μ_γ for line A = 4·303; for line Z = 4·193. Vibrations parallel axis Z.
μ_β „ = 4·046; „ = 3·919. „ „ „ Y.

Prism II.—The refracting edge of this prism was parallel to the cleavage and to the X axis of the crystal. One face of the prism was perpendicular to c (001) and therefore perpendicular to the cleavage, the second was inclined to the first at an angle of 9° 15′. Great difficulty was experienced in polishing the faces of this prism, and it was found necessary to cement the face perpendicular to the cleavage on to a plate of glass. Placed on the spectrometer, two widely separated red patches were seen, but the definition was not sufficiently good to enable the line A to be detected, much less the line Z. The telescope was therefore set on what was judged to be the central brightest portion of each patch corresponding roughly to the region about midway between A and Z. The mean deviations observed were 21° 4½′ and 30° 40½′ respectively, whence follow as above :—

$\mu_\alpha = 3{\cdot}141$. Vibrations parallel axis Y.
$\mu_\beta = 3{\cdot}993$. „ „ „ X.

Discussion of results.—The main source of error in the above observations is the uncertainty of the value of the prism-angle, any small inaccuracy in this determination having a great influence on the calculated value of μ, when such acute-angled prisms have to be employed. Thus an error of 1′ in the value of the angle of prism I

alters the corresponding value of μ by 0·007. An error of the same magnitude in the determination of the deviation is less serious, changing the value of μ by 0·002. There is no particular difficulty in getting fair readings for the deviation of the line A, but, owing to its faintness, Z is much harder to observe. The nature of the reflections from the faces of prism I were such as to render the value of its angle uncertain by about 1′ of arc. The values of μ_β and μ_γ are therefore probably correct within $\pm$ 0·01. In the case of prism II the uncertainty is somewhat greater, and A and Z cannot be distinguished. A probable value of μ_α for the line A can, however, be deduced from the numbers quoted above on the assumption that the double refraction $\mu_\beta - \mu_\alpha$ is about the same for A as for the region midway between A and Z. Subtracting then 0·852 from 4·046 we get 3·194 as the value of μ_α for the line A.

The optical scheme of antimonite for red light of wave-length 760 is therefore as follows:—

Plane of the optic axis parallel to a (100). Acute bisectrix perpendicular to c (001). Double refraction strong, negative.

$\mu_\alpha = 3{\cdot}194$. $\mu_\beta = 4{\cdot}046$. $\mu_\gamma = 4{\cdot}303$. Whence $2V = 25° 45'$.

In addition to exhibiting very strong double refraction, antimonite is remarkable as showing an extraordinarily high degree of dispersion in the region under consideration. Thus for β we have $\mu_A - \mu_Z = 0{\cdot}127$ and for γ we have $\mu_A - \mu_Z = 0{\cdot}110$. Carvallo's[1] measurements enable us to compare this dispersion with that of calcite, for which he found $\mu_{ord.}$ (760) = 1·6501 and $\mu_{ord.}$ (832) = 1·6477; difference = 0·0024. Thus the difference of the refractive indices in the case of antimonite is more than fifty times as great as in that of calcite.

Further, these results are of special interest in so much as they supplement the work of E. C. Müller[2], who by a study of the constants of elliptic polarization of the light reflected from fresh cleavage-surfaces of antimonite was enabled to draw the dispersion curves for the region extending from G to C.

In view of the information already gained it seems desirable that the investigation should be extended as far as possible into the infra-red region. Further, there seems ground for believing that with the aid of the experience now acquired, it may be possible to prepare

[1] Compt. rend. Acad. Sci. Paris, 1898, vol. cxxvi, p. 950.
[2] Neues Jahrb. Min., 1903, Beil.-Bd. xvii, pp. 187–251.

a prism cut across the cleavage with surfaces good enough to enable A and Z to be recognized.

Work in both these directions is now in progress, and it is hoped that it may be possible before long to communicate further results to the Society.

Mineralogical Museum,
Cambridge.
December 5, 1906.

The chemical composition of Lengenbachite.

By A. Hutchinson, M.A., Ph.D.
Demonstrator of Mineralogy in the University of Cambridge.

[Read June 14, 1905.]

LENGENBACHITE is one of the interesting minerals which occur in the dolomite of the Binnenthal, and we owe our knowledge of it, as of many other new species, to the careful investigations conducted in recent years by Mr. R. H. Solly at that remarkable locality. The crystallographic and physical characters, so far as they have proved capable of determination, have been already described by Mr. Solly in the pages of this Magazine (vol. xiv, p. 78). The material which he kindly placed in my hands for chemical examination consisted of cleavage-plates, exhibiting brilliant metallic lustre, and of foliated aggregates of thin greyish-black crystals. Some of the crystals were partially covered with a thin, white incrustation readily removed by boiling dilute hydrochloric acid, a reagent which appeared to be without action on the lengenbachite. After removal of the incrustation, whose nature was not further examined, advantage was taken of the highly perfect cleavage to split the crystals into as thin flakes as possible, in order that minute crystals of iron-pyrites imbedded in the lengenbachite might be picked out. Although this operation was carried out with great care, it seems not unlikely that a little pyrites may have escaped detection and the small quantity of iron subsequently estimated may possibly have been derived from this source. The cleavage-plates were next reduced to fine powder in an agate mortar, a process rendered tedious by the toughness of the laminae, but which was found to be absolutely necessary in order to ensure successful decomposition by chlorine gas.

Specific Gravity.—A careful determination of the specific gravity made on 2·231 gram of the powder, afterwards used for analysis, gave the value 5·85 at 15·5°C. compared with water at 4°C.

Analysis.—For the purpose of quantitative analysis, the substance, which had been found to contain lead, silver, copper, arsenic, antimony, and sulphur, was placed in a porcelain boat and decomposed by a current of chlorine in a glass tube, which was gently heated towards the end

of the reaction. The elements contained in the residue and in the distillate were separated and estimated by the usual methods, and during the course of the work a small quantity of iron was found. Sulphur was determined in two independent experiments and control estimations of the arsenic also obtained; owing to an accident, a duplicate determination of the antimony was unfortunately spoilt. The results are exhibited in columns I, II, and III of the table below:—

	I.	II.	III.	Mean.	Atomic ratios.		
Pb ...	57·89	—	—	57·89	0·2798		
Ag ...	5·64	—	—	5·64	0·0522	÷2	0·3274	1·761
Cu ...	2·36	—	—	2·36	0·0371			
Fe ...	0·17	—	—	0·17	0·0030			
As ...	(13·29)	13·41	13·52	13·46	0·1795		0·1859	1·000
Sb ...	0·77	—	—	0·77	0·0064			
S ...	—	19·35	19·32	19·33	0·6032		0·6032	3·244
				99·62				

The weights of material used in each of the above analyses were as follows:—analysis I, 0·8750 gram; analysis II, 0·8987 gram; analysis III, 1·2828 gram. The weight of the mixture of chlorides remaining in the porcelain boat after the decomposition by chlorine was finished amounted in analysis I to 0·7933 gram. This weighing affords some check on the accuracy of the subsequent work, for the weight of the mixture of chlorides which should be formed from 0·8750 gram of lengenbachite can be calculated on the assumption that the percentages of lead, silver, copper, and iron given in column I above are correct. On calculation this weight was found to be 0·7938 gram, an agreement which may be considered satisfactory.

Chemical Formula.—The interpretation of the analytical results, though not wholly devoid of difficulty, offers some points of interest. If we assume in the first place that the small quantity of antimony is replacing an equivalent amount of arsenic, and secondly that two atoms of silver or of copper can, in this mineral, play the part of one atom of lead, and if the iron be treated as an essential constituent, then we see from an inspection of the columns headed atomic ratios that Pb : As : S = 1·761 : 1 : 3·244 or 7 : 4 : 13, very nearly. The empirical formula of the mineral is therefore $Pb_7As_4S_{13}$ or, as it may also be written, $7PbS . 2As_2S_3$. Accepting this interpretation, we find that lengenbachite takes its place naturally in the long series of compounds of lead, arsenic, and sulphur, filling a gap between guitermanite and

jordanite, just as liveingite, baumhauerite, and rathite find their places between sartorite and dufrenoysite.

$PbS.As_2S_3$, Sartorite	$2PbS.As_2S_3$, Dufrenoysite
$5PbS.4As_2S_3$, Liveingite	$3PbS.As_2S_3$, Guitermanite
$4PbS.3As_2S_3$, Baumhauerite	$7PbS.2As_2S_3$, Lengenbachite
$3PbS.2As_2S_3$, Rathite	$4PbS.As_2S_3$, Jordanite

Another possible interpretation must not, however, be lost sight of. It may be that the number of the lead atoms bears a fixed relation to the number of the atoms of silver and of copper, and a consideration of the ratios lends some support to this view. Thus, if we assume that the iron is present as pyrites, and omit FeS_2 from the calculation, we find that the ratios are as follows:—

$$Pb:(Ag, Cu):As:S = 0{\cdot}2798:0{\cdot}0893:0{\cdot}1859:0{\cdot}5972$$
$$= 6{\cdot}02:1{\cdot}92:4:12{\cdot}85.$$

A result which leads to the formula

$$Pb_6(Ag, Cu)_2As_4S_{13} \text{ or } 6PbS.(Ag, Cu)_2S.2As_2S_3.$$

That the ratio Pb:(Ag, Cu) approaches in this case very nearly to three to one is an interesting fact. Whether it is a mere coincidence or whether, on the other hand, it has deeper significance can only be satisfactorily determined when more material is available for analysis. In the meantime the formula

$$6PbS.(\tfrac{3}{5}Ag, \tfrac{2}{5}Cu)_2S.2As_2S_3$$

has the merit of expressing the analytical results with tolerable exactitude, the corresponding percentage composition being as follows:—

Pb, 58·07; Ag, 6·03; Cu, 2·38; As, 14·03; S, 19·49.

Mineralogical Museum,
Cambridge.

Note on 'Feather-ore': identity of 'Domingite' (='Warrenite') with Jamesonite.

By L. J. Spencer, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read March 22, 1904.]

THE formula $2PbS.Sb_2S_3$, given for jamesonite in all the textbooks, does not belong to jamesonite at all, but to the 'Federerz' ('feather-ore') from Wolfsberg in the Harz analysed by H. Rose in 1829, and for which the mineralogical names wolfsbergite (Huot, 1841) and plumosite (Haidinger, 1845) have been proposed. Rose's formula for the cleavable jamesonite from Cornwall was $3PbS.2Sb_2S_3$. In 1860 Rammelsberg[1] united these, together with heteromorphite, under the name jamesonite and with the formula $2PbS.Sb_2S_3$: this has since been followed in the textbooks, but, as will be pointed out below, it is very probable that there are here three distinct mineral species.

The original jamesonite formula, $3PbS.2Sb_2S_3$, thus came to be forgotten, and when it again appeared in the literature it was consequently assumed to represent a new species. In this way one of the sulphantimonites of lead from Colorado analysed by Mr. L. G. Eakins[2] in 1888 was named 'domingite' by Professor Groth[3] in 1889, and 'warrenite' by Eakins[4] himself in 1890. The latter name has been generally accepted, although 'domingite' is the earlier of the two.

Eakins's formula, $3(Pb,Fe)S.2Sb_2S_3$, was deduced from a single analysis, made on material described as occurring in matted, wool-like aggregates of acicular crystals, and known locally as 'mineral-wool'. The results of his analysis (I) are compared below with the mean (II) H. Rose's

[1] For fuller historical details see Min. Mag., 1899, vol. xii, p. 58.

[2] L. G. Eakins, 'Two sulphantimonites from Colorado.' Proc. Colorado Sci. Soc., 1888, vol. iii, pp. 73–76; Amer. Journ. Sci., 1888, ser. 3, vol. xxxvi, pp. 450–453. The second of these minerals, which was described as freieslebenite, has since been shown to be boulangerite.

[3] 'Tabell. Uebersicht d. Mineralien.' Braunschweig, 1889, 3rd edit., p. 30.

[4] Amer. Journ. Sci., 1890, ser. 3, vol. xxxix, p. 74; Bull. United States Geol. Survey, 1890, no. 60, p. 117.

analyses of Cornish jamesonite and with Dr. G. T. Prior's analysis (III) of crystallized jamesonite from Bolivia [1].

	S.	Sb.	Pb.	Fe.	Cu.	Ag.	Mn.	Gangue.	Total.
I.	21·19	36·34	39·33	1·77		traces		0·52	99·15
II.	22·56	34·26	40·18	2·63	0·18	—	—	—	99·81
III.	20·52	34·53	41·18	2·76	0·26	0·01	—	—	99·26

In the absence of any determinable physical or crystallographic characters, this analysis is scarcely sufficient to define a mineral species, especially among the sulphantimonites of lead. There is no guarantee that the material analysed was all of one kind. Nevertheless, on comparing the analysis of 'domingite' with the few analyses that have been made of cleavable jamesonite, it will be seen that they agree sufficiently closely to suggest an identity.

A specimen (British Mus. no. 84697) of 'domingite', collected in 1899 by Mr. E. R. Warren at the original locality (Domingo mine, Elk Mountain mining district, Gunnison Co., Colorado), was obtained in that year, through Mr. W. F. Ferrier, for the British Museum. The matrix of this specimen, collected twelve years after the abandonment of the mine, does not, however, agree with that of the original specimens, also collected by Mr. Warren, and described by Mr. Eakins as 'a highly decomposed gangue rock of siliceous material mixed with some calcite'. In the British Museum specimen the felted aggregates of short and straight needles fill cavities in pink rhodochrosite; the latter encloses a few specks of tetrahedrite, iron-pyrites, and arsenopyrite, and in the cavities it is crystallized as curved rhombohedra.

Attempts were made to measure the very minute, striated needles on the goniometer, but without result. It was, however, determined that the needles are brittle and not flexible. For reasons stated below, this latter character indicates that the material must be referred to jamesonite.

'Domingite' is thus one of the black, metallic minerals, capillary in form, to which the name 'feather-ore' would be applied.

Previous to Rose's analysis of 1829, 'feather-ore' was referred to stibnite, later it was referred to plumosite, while at the present time it is included under jamesonite. As a matter of fact 'feather-ore' may be stibnite [2] or any of the several acicular (orthorhombic) sulphantim-

[1] An account of this will be given in the next number of this Magazine.

[2] E. Kaiser, 'Haarförmiger Antimonglanz aus Rheinland und Westfalen.' Zeits. Kryst. Min. 1896, vol. xxvii, pp. 49–51. I have also found several specimens of capillary stibnite amongst the jamesonites in the British Museum collection.

nites of lead. Of 'feather-ores' containing lead, antimony, and ulphur there are, as indicated by external characters, at least two inds, viz.:

(*a*) Flexible 'feather-ore'.
(*b*) Brittle 'feather-ore'.

The fine capillary crystals of the former may be bent double without reaking, and when released they spring back to their original position. his would scarcely be possible if they possessed a good cleavage perendicular to their length, as does jamesonite. Because of this cleavage, rittle 'feather-ore' is no doubt in all cases identical with jamesonite.

On the other hand, flexible 'feather-ore' may be either zinckenite, umosite, boulangerite, or meneghinite, but it seems impossible to stinguish between these when only capillary crystals are available. In ne absence of any characteristic feature it would be impossible to llect material all of one kind for chemical analysis. There is nothing show that these finely acicular aggregates are not mixtures of various lphantimonites of lead, or of these with stibnite. Further, when the irs are closely examined with a lens or under the microscope there may ten be seen minute crystals of galena threaded on them like beads on string. Analyses of such undeterminable material are useless, and n only lead to error. I have for several years been looking out for terial suitable for detailed examination, but so far without success.

Zinckenite, boulangerite, and meneghinite appear to be well established distinct mineral species, but the existence of plumosite ($2PbS . Sb_2S_3$) based only on the chemical analyses of felted masses of capillary stals. The published analyses of 'feather-ore' which agree approxitely with this formula are quoted below:[1]—

	I.	II.	III.	IV.	V.	Calculated $2PbS . Sb_2S_3$.
S ...	19·72	18·40	19·25	20·49	19·84	19·68
Sb ...	31·04	30·19	29·24	27·72	28·53	29·55
Pb ...	46·87	47·68	49·31	48·38	49·74	50·77
Fe ...	1·30	0·26	—	3·47	0·53	—
Cu ...	—	1·11	2·00	—	—	—
Zn ...	0·08	1·09	0·21	—	—	—
	99·01	98·73	100·01	100·06	98·64	100·00

[1] Three analyses of 'Federerz' agreeing very closely with the above formula are also given by C. Guillemain, Inaug.-Diss., Breslau, 1898, pp. 21, 24.

I. H. Rose, Ann. Phys. Chem. (Poggendorff), 1829, vol. xv, p. 471. 'Federerz' from Wolfsberg, Harz.

II. E. Bechi, quoted by Meneghini, Amer. Journ. Sci., 1852, ser. 2, vol. xiv, p. 60. Capillary; from Bottino, Tuscany.

III. Ditto. Acicular; same locality.

IV. E. Bořický[1], quoted by V. von Zepharovich, Sitz.-Ber. Akad. Wiss. Wien, 1867, vol. lvi, Abth. I, p. 37. Fine elastic needles described as 'boulangerite'; from Przibram, Bohemia.

V. G. Baumert, quoted by O. Luedecke, 'Die Minerale des Harzes,' Berlin, 1896, p. 127. Felty mass of very fine fibres; from Schwenda, Harz.

Flexible 'feather-ore' containing lead, antimony, and sulphur must therefore be removed from jamesonite, and in collections can only be placed in a natural history group to which the name plumosite may be conveniently applied, although specimens so placed are not necessarily the same as Rose's plumosite.

In a previous paper[2] I have pointed out that heteromorphite must also be removed from jamesonite. The former is monoclinic with pyramidal cleavages, whilst the latter is orthorhombic with a basal cleavage.

In conclusion, the several sulphantimonites of lead are tabulated below, but the formulae assigned to them can only be regarded as provisional. They fall into two dimorphous groups. Those of the orthorhombic group occur as acicular and capillary crystals or as fibrous masses, whilst those of the monoclinic group occur as short pyramidal and tabular crystals or as granular masses. The former usually contain a small percentage of iron, whilst the latter contain none.

Orthorhombic.[3]		Monoclinic.	
Zinckenite,	$PbS . Sb_2S_3$	Plagionite,	$5PbS . 4Sb_2S_3$
Jamesonite,[4]	$7(Pb, Fe)S . 4Sb_2S_3$	Heteromorphite,	$7PbS . 4Sb_2S_3$
Plumosite,	$2PbS . Sb_2S_3$	Semseyite,	$9PbS . 4Sb_2S_3$
Boulangerite,	$5PbS . 2Sb_2S_3$		
Meneghinite,	$4PbS . Sb_2S_3$		

[1] Bořický also analysed a massive, fibrous 'jamesonite' from Przibram, which gave results agreeing with this formula (loc. cit., p. 32).

[2] 'Plagionite, heteromorphite and semseyite as members of a natural group of minerals.' Min. Mag., 1899, vol. xii, pp. 55–68.

[3] 'Schulzite' ($5PbS . Sb_2S_3$) and 'plumbostibite' ($10PbS . 3Sb_2S_3$) may possibly also belong to this group, but not geocronite (= kilbrickenite) since this appears to be a double salt, $5PbS . Sb_2S_3 + 5PbS . As_2S_3$ (Min. Mag., 1902, vol. xii, p. 188).

[4] This formula is deduced from the analysis, quoted above, of crystallized jamesonite from Bolivia.

Note on Gypsum crystals found lining a disused well at chemical works.

By C. J. Woodward, B.Sc., F.G.S.

[Read November 14, 1905.]

BEFORE the value of hydrochloric acid for chlorine manufacture was recognized by soda-crystal makers, it was a common practice to get rid of the unpleasant fumes in the cheapest and most convenient way possible. At Messrs. Chance's works at Oldbury, near Birmingham, this was done by turning the gases from the salt-cake furnaces into a culvert which ran through some portion of the works. The better to condense the fumes, it seems probable that a brook, which runs near the works, was diverted into the culvert, thus forming a rough condenser. Some thirty years or so ago, when alterations were being made at these works, a culvert of this description was unearthed and found to be lined with crystals of gypsum, which had formed on the brickwork. An old well, which was opened, was also studded with beautiful tufts of crystals. I am indebted to Mr. A. M. Chance for a handsome specimen with numerous attached crystals of gypsum, and also for some stereoscopic slides showing the well with the crystals *in situ*.

The crystals on this specimen are from 20 to 30 mm. in length. They are elongated in the direction of the vertical axis, and are slightly tabular owing to the predominance of the form $b\{010\}$. Mr. T. V. Barker has kindly determined the forms present, and finds them to be only $b\{010\}$, $m\{110\}$, $n\{\bar{1}11\}$.

The deposition of these crystals was produced, I presume, by the gradual weakening of a solution of calcium sulphate in hydrochloric acid. There must have been plenty of lime and sulphuric acid about the works to furnish the gypsum. Calcium sulphate would be taken up by the hydrochloric acid, and subsequently, when the wasteful method of condensing the acid was discontinued, the acid solution would gradually weaken and crystals of gypsum be deposited.

Crystallography of Sartorite from Binn.

(*With Plate V.*)

By Charles O. Trechmann, Ph.D., F.G.S.

[Read June 12, 1906.]

LITERATURE[1].

G. vom Rath, 'Mineralogische Mittheilungen (Fortsetzung III): II. Skleroklas.' Ann. Chem. Phys. (Poggendorff), 1864, vol. cxxii, pp. 380–387.

H. Baumhauer, 'Ueber den Skleroklas von Binn.' Sitzungsber. k. preuss. Akad. Wiss. Berlin, 1895, pp. 243–252.

R. H. Solly, 'Sulpharsenites of lead from the Binnenthal.' Min. Mag., 1900, vol. xii, pp. 282–297 (Sartorite on pp. 286 and 297). Translation in Zeits. Kryst. Min., 1891, vol. xxxv, pp. 321–344.

W. J. Lewis, 'A large crystal of sulpharsenite of lead from the Binnenthal.' Min. Mag., 1903, vol. xiii, p. xxxiv. (Analysis by H. Jackson.)

R. H. Solly, 'On sartorite . . . and other minerals from the Binnenthal.' Min. Mag., 1904, vol. xiv, p. xx. (Title only; abstract, giving angular elements, in 'Nature,' 1903, vol. lxix, p. 142.)

H. Baumhauer, 'Die Mineralien des Binnenthals.' Bull. Murithienne, Soc. valais. sci. nat., 1905, p. 35–49.

THE mineral sartorite (of Dana) or scleroclase (of v. Waltershausen) appears to have been found much more frequently in latter years in the well-known dolomite at the Lengenbach, in the Binnenthal, Switzerland, than was formerly the case, and it may now be considered to be one of the commonest of the group of sulpharsenites of lead which have made this locality famous. Large, detached, longitudinally striated, prismatic crystals, mostly devoid of terminal faces, have been especially frequent, the majority of which are doubtless sartorites.

Notwithstanding this abundance of material, there still exists some doubt respecting the system in which this mineral crystallizes. This is due to the peculiar development of a large proportion of the crystals, which are heavily striated and grooved in one direction, and without

[1] A more complete list of the earlier references is given by R. H. Solly, Min. Mag., 1900, vol. xii, p. 282.

terminal faces, both ends of the crystal being attached to the dolomite matrix. When, in rarer cases, terminal faces are developed they appear brilliant, smooth, and unstriated, but all belonging to a single zone perpendicular to the striated one, thus affording no assistance towards the determination of the parameters. When pyramidal faces are present, which is exceedingly rare, they are frequently rounded or poorly developed on larger crystals, and on small ones either too minute, or situated in such a position with respect to the matrix that a removal of the crystal is practically impossible, owing to its extreme brittleness.

The latest detailed investigation of sartorite is due to Baumhauer (1895), who examined four crystals and determined on them a series of new forms. He enumerates a total of fifty-nine observed forms, among which are thirteen pyramids, though, as he himself states, a few of them are somewhat uncertain. Baumhauer describes, in agreement with the earlier investigation of vom Rath, this mineral as crystallizing in the orthorhombic system, though, as pointed out by himself, many of the forms only appear as single faces, whilst others exhibit very high and complicated indices.

The chemical composition is further elucidated by the analyses published by Solly (1900). These were made by Jackson on carefully selected crystals measured by the former, and lead to the assumption of the same formula as that adopted by vom Rath, viz. $PbS . As_2S_3$. A later analysis by Jackson (Lewis, 1903) also agrees closely with this formula, whilst Baumhauer, from an analysis made by König, is led to the formula $3(PbS . As_2S_3) + 2PbS . As_2S_3$.

The specific gravity, viz. 4·98 Solly, 5·05 Baumhauer, and 5·393 v. Waltershausen (cf. v. Rath), also shows some discrepancy. Solly (1903) further states that sartorite crystallizes, not in the orthorhombic, but in the monoclinic system, with the elements:

$$\beta = 88°31',\ (100):(101) = 54°45',\ \text{and}\ (010):(111) = 69°52\tfrac{1}{2}'.$$

These data I have, however, been unable to harmonize with my own results.

On the occasion of a visit to the Binnenthal in August, 1904, I spent a day in company of Mr. Solly, with the men who work the dolomite quarry. A blasting shot was fired, and among other minerals a considerable number of specimens of sartorite were found, one or two of which exhibiting pyramidal faces. Among these and other purchased specimens were two which attracted attention on account of the brilliancy and perfection of form of small, presumably sartorite, crystals

which they contained. These crystals form the principal subject of the following investigation.

The first specimen, about 4 cm. and 3 cm. in size, consisted of the usual white, granular dolomite, with some yellowish, coarser grained dolomite, some quartz, and a vein of massive sartorite, together with small crystals of realgar, pyrites, and a couple of minute binnites. In a small cavity was a crystal of sartorite of less than 2 mm. in size, on which a number of broad, smooth and highly polished faces were visible, developed in two zones perpendicular to each other, and on one corner, partially hidden by the matrix, a number of distinct pyramidal planes could be observed.

The second specimen, of similar size and component minerals with the exception of the realgar, also exhibited a small cavity in which, attached directly to the dolomite, was a group of three crystals. This group I was fortunately able to remove without fracture. It consisted of a doubly terminated sartorite about 2 mm. long and 1 mm. in each of the other dimensions, to which was attached a slightly smaller and shorter crystal of the same mineral, in what appeared to be a twinned position at an angle of about 45°, but in such a manner that the zone of the terminal faces of the second crystal was perpendicular to the same zone of the larger crystal. To the smaller crystal was attached a third crystal, at an indeterminate angle, which appeared to be rathite. The two sartorite crystals are distinguished by a beautifully developed series of terminal faces.

In the removal of the crystal of sartorite from the first specimen great care was exercised in the endeavour to obtain it unfractured; nevertheless, at the last moment, it broke, with an audible explosion, into several pieces. Very fortunately, however, the largest piece consisted of the greater part of the crystal, which had been visible on the matrix, and represented a practically complete individual. A second, smaller fragment consisted of an almost complete twinned crystal. The exact relative position of the larger to the smaller crystal was unfortunately not determinable, as the second crystal, while on the matrix, was hidden from view. It is, however, very probable that they were attached parallel to each other. These two crystals are referred to below as No. 1 and No. 2 respectively; the doubly terminated crystal from the second specimen as No. 3, and the one attached to it, in an apparently twinned position, is called No. 4. Nos. 5, 6, and 7 were received later.

The preliminary examination of Nos. 1 and 2, which are both under

1 mm. in size, was made with the aid of a Zeiss-Greenough binocular microscope—a most efficient instrument for the purpose—and powers of 35 to 65 diameters, with the result that both crystals exhibited a conspicuous monoclinic habit, which I have endeavoured to reproduce as closely as possible after nature in figs. 1 and 3, plate V, in orthogonal projection on the plane of symmetry. Figs. 2 and 4 are meant to illustrate the same crystals in an ideal development, in order to show the zonal relationship of the faces to each other. The orthodomes therefore represent the macrodomes of the orthorhombic interpretation, and the prisms those of the brachydomes. The former, as the measurements indicated, were only found in single faces, whilst the latter usually appeared in symmetrical pairs in adjacent quadrants. A striking feature on crystal No. 1 was the extraordinarily rich development of the pyramidal faces, in which the negative hemipyramids in the two opposite octants largely exceed the positive ones in number, a relationship which is reversed in crystal No. 2. It is also worthy of note that many of the combination-edges of the pyramid-faces to each other and to the prism-faces incline considerably from right to left, being all parallel with each other in the projection. The feature, however, which gives the strongest monoclinic character to these two crystals is the presence of a number of distinct twin-lamellae, quite similar to, though narrower than, those so well known on jordanite, which traverse the pyramid- and clinodome-faces from top to bottom of the crystals, parallel to the orthopinacoid, but which are invisible on the prism-faces. The latter feature would seem to exclude the possibility of the anorthic system for these crystals. The majority of these twin-lamellae have been indicated on figs. 1 and 3 by dotted lines, and it will be noticed that in both crystals they appear in greatest number towards the central portion of the crystal, and that the outlying faces, i. e. those nearest to the orthopinacoids, are in some cases quite devoid of them. In harmony with this feature is the complete and undisturbed development of the large, smooth, and brilliant orthodome faces in the vicinity of a (100), and a considerable striation and grooving of the same faces nearer to c (001). This is not so apparent on the other side of the crystal around $a'(\bar{1}00)$, where the crystal was closely invested by the matrix; here there is a considerable striation of the orthodomes and a repetition with a'. The face $a(100)$ is narrow, but well developed, giving a very satisfactory reflection on the goniometer. $a'(\bar{1}00)$ is larger, but terraced by repetition. The large orthodome- and the principal prism-faces are perfectly even and highly polished and give perfect

reflections. The pyramid- and clinodome-faces, under a certain reflective angle of the light, appear slightly etched and velvety in appearance, but give, notwithstanding their minute dimensions, exceedingly good undisturbed reflections, which are very slightly affected by the faint secondary reflections of the twin-lamellae. The combination-edges of the various pyramids with one another and with the prisms and orthodomes are usually rounded and with a fused-like appearance, whilst those of the larger orthodomes and prisms are sharp and linear. The basal pinacoid c (001) was narrow, striated, and repeated, and unsuited for exact measurement, and the clinopinacoid b (010) was very narrow and rounded. Attached to the lower end of crystal No. 1 (see fig. 1) there remained a fragment of another crystal, marked II, which, according to the two well-developed orthodome-faces $2d$ ($\bar{2}01$) and $\frac{8}{3}d$ ($\bar{8}03$), represents a second individual in twinned position to the main crystal, and which would therefore form with the main crystal a contact or juxtaposition-twin on the same law as the twin-lamellae, viz. twin-plane a (100), but with the composition-plane perpendicular to the same. The two small visible pyramid-faces indicated on the figure were not elucidated.

Crystal No. 1 was measured through in almost all directions where zones could be followed, with the result that the monoclinic habit was distinctly confirmed, in harmony with the general appearance as already described. The measurements of the pyramid-faces, on account of their minute size and the rather weak, though distinct, reflections, were not used for fundamental angles, for which the very best reflections of the orthodomes and prisms were utilized. After some preliminary calculations, the following angles were selected for the determination of the parameters:

$$a : -d = (100) : (101) = \infty\bar{P}\infty : -\bar{P}\infty = 40°\,24\tfrac{1}{2}'$$
$$a' : \quad d = (\bar{1}00) : (\bar{1}01) = \infty\bar{P}\infty : \bar{P}\infty = 53°\,25'$$
$$a : \quad f = (100) : (110) = \infty\bar{P}\infty : \infty P = 51°\,16'$$

From which were calculated:

$$a : b : c = 1{\cdot}27552 : 1 : 1{\cdot}19487;$$
$$\beta = 77°\,48'.$$

The prisms therefore correspond to brachydomes of vom Rath and the orthodomes to his macrodomes, and I have retained the same letters for the generalized symbols of these forms, viz. f for the prisms and d for

the orthodomes, to facilitate a comparison with the previous descriptions and figures of this mineral.

The axes $a : b : c$ selected by me furthermore correspond to the axes $c : b : a$ of vom Rath, with the distinction that my axes a and c are about twice as long as vom Rath's axes, which are $a : b : c = 0{\cdot}539 : 1 : 0{\cdot}619$, whereby a system of axes of almost equal length has been obtained.

From this set of parameters I have calculated the indices of all the forms which were observed with reasonable certainty on crystals Nos. 1 and 2, and which are enumerated in Table I, together with the observed and calculated angles, the quality of the measurement, such as v. g. (very good), ca. (circa), &c., the number of observations of each face, and the nature of the face.

On the two crystals were observed 87 forms, consisting of the 3 pinacoids, 17 prisms, 6 clinodomes, 19 positive and 7 negative hemi-orthodomes, 35 pyramids, divided into 16 positive and 19 negative hemipyramids. Of the orthodomes only the following four pairs have corresponding indices in the positive and negative octants: $\pm 4d$, $\pm \frac{4}{3}d$, $\pm d$, and $\pm \frac{2}{7}d$. The eight pairs of pyramids with corresponding indices in the positive and negative octants are the following:

$e = \bar{1}11$ $r = 111$	$\pm$P	$v = \bar{2}41$ $q = 241$	$\pm 4\grave{\mathrm{P}}2$
$\gamma = \bar{4}41$ $o = 441$	± 4P	$\tau = \bar{3}22$ $n = 322$	$\pm \frac{3}{2}\mathrm{P}\frac{3}{2}$
$h = \bar{1}22$ $p = 122$	$\pm\grave{\mathrm{P}}2$	$x = \bar{2}11$ $\nu = 211$	$\pm 2\bar{\mathrm{P}}2$
$g = \bar{2}43$ $\mu = 243$	$\pm\frac{4}{3}\grave{\mathrm{P}}2$	$\pi = \bar{7}22$ $\mathrm{V} = 722$	$\pm \frac{7}{2}\bar{\mathrm{P}}\frac{7}{2}$

At the end of Table I are added four further prisms, which were not observed on crystals Nos. 1 and 2. On none of the seven measured crystals was there found any indication of a plane at 90° to a (100), which would correspond with vom Rath's macropinacoid.

Crystal No. 2 requires a somewhat more detailed description. It was very small, barely $\frac{2}{3}$ mm. in the direction of the b axis, $\frac{1}{3}$ mm. in the a, and $\frac{1}{2}$ mm. in the c axis, and in habit very different from No. 1. The orthodome-zone was badly developed, much striated, and repeated, with very few distinct reflections. The orthopinacoid a (100) was very minute and curved, and the basal pinacoids c (001) were narrow, striated, and repeated, with poor reflections. The pyramid-faces were, however, smooth and polished, with rounded combination-edges, and

TABLE I.

LIST OF THE FORMS OBSERVED ON CRYSTALS No. 1 AND No. 2; WITH THE OBSERVED AND CALCULATED ANGLES.

No.	Letter or Symbol.	Indices. Miller.	Indices. Naumann.	Crystal. No. 1.	Crystal. No. 2.	Angles to $a = 100$. Calculated.	Angles to $a = 100$. Measured.	Angles to $a = 100$. Value.	Angles to other faces. Face.	Angles to other faces. Calculated.	Angles to other faces. Measured.	Angles to other faces. Value.	Number of Measured Angles.	Remarks.
Pinacoids :—						° ′	° ′			° ′	° ′			
1	a	100	$\infty \bar{P} \infty$	+	+	0 0								
2	b	010	$\infty \breve{P} \infty$	+										
3	c	001	0 P	+	+	90 0	90 4	ca.						good face.
Prisms :—														
4	$20\bar{f}$	20.1.0	$\infty \bar{P} 20$		+	77 48	77 44	fair					1	very narrow, curved.
							77 37	ca.						
5	$5\bar{f}$	510	$\infty \bar{P} 5$	+	+	3 34	3 34	ca.					4	very narrow, uneven.
6	$\frac{9}{2}\bar{f}$	920	$\infty \bar{P} \frac{9}{2}$			14 0	13 53	ca.						
7	$4\bar{f}$	410	$\infty \bar{P} 4$	+			14 2	ca.					1	very narrow.
8	$\frac{7}{2}\bar{f}$	720	$\bar{P} \frac{7}{2}$	+		15 29	15 29	fair					2	narrow.
9	$3\bar{f}$	310	$\infty \bar{P} 3$	+		17 19	17 8	g.					1	good.
10	$\frac{11}{4}\bar{f}$	11.4.0	$\infty \bar{P} \frac{11}{4}$		+	19 36	19 31	g.					1	good.
11	$\frac{5}{2}\bar{f}$	520	$\infty \bar{P} \frac{5}{2}$		+	22 34	19 33	g.					2	narrow, distinct.
12	$\frac{9}{4}\bar{f}$	940	$\infty \bar{P} \frac{9}{4}$	+		24 23	21 35	g.					1	narrow, distinct.
13	$2\bar{f}$	210	$\infty \bar{P} 2$	+		26 30	24 38	g.					1	narrow, distinct.
14	$\frac{11}{7}\bar{f}$	11.7.0	$\infty \bar{P} \frac{11}{7}$	+	+	28 59	26 30	v.g.					2	large, good.
					+	31 56	29 0	ca.					1	narrow.
						38 26	31 54	v.g.					2	large and smooth.
							38 18	fair					1	good.

TABLE I (*continued*).

15	$\frac{3}{2}\bar{f}$	320	$\infty\bar{P}\frac{3}{2}$	+	+	39 44	39 44 39 48	v.g. v.g.	001	80 39	80 32	g.	3	large and smooth.
16	$\frac{4}{3}\bar{f}$	430	$\infty\bar{P}\frac{4}{3}$		+	43 5	42 55	g.					1	narrow, distinct.
17	f	110	∞P	+	+	Fund.	51 16	v.g.	001	82 24	82 31	g.	3	large and smooth.
18	$2\grave{f}$	120	$\infty\grave{P}2$	+	+	68 9	68 2 68 4	ca. ca.	001	85 29	85 33	g.	3	very narrow.
19	$3\grave{f}$	130	$\infty\grave{P}3$		+	75 2	75 48	ca.					1	very narrow, doubtful.
20	$1\frac{1}{2}\grave{f}$	2.13.0	$\infty\grave{P}1\frac{1}{2}$	+		82 58	82 56	ca.					1	very narrow.
Clinodomes :—														
21	a	023	$\frac{2}{3}\grave{P}\infty$	+		80 24			001	37 54	37 57	ca.	1	minute.
22	κ	045	$\frac{4}{5}\grave{P}\infty$	+		81 7			001	43 3	43 3	v.g.	1	distinct.
23	i	011	$\grave{P}\infty$	+		82 6	82 3	g.	001	49 26	49 23	g.	1	distinct.
24	y	065	$\frac{6}{5}\grave{P}\infty$	+		82 57			001	54 29	55 0	g.	1	minute, uneven.
25	l	085	$\frac{8}{5}\grave{P}\infty$	+		84 17			001	61 51	61 45	ca.	1	minute.
26	w	041	$4\grave{P}\infty$	+		87 28	87 37	ca.	001	77 55	78 7	ca.	1	long and narrow.
Orthodomes, positive :—														
27	$9d$	$\bar{9}01$	$9\bar{P}\infty$	+		6 46	6 53	ca.					1	very narrow.
28	$8d$	$\bar{8}01$	$8\bar{P}\infty$	+		7 39	7 38	fair					1	distinct, striated.
29	$\frac{9}{2}d$	$\bar{9}02$	$\frac{9}{2}\bar{P}\infty$	+		13 43	13 50	v.g.					1	good and smooth.
30	$2\frac{1}{6}d$	$\overline{21}.0.5$	$2\frac{1}{6}\bar{P}\infty$	+		14 43	14 48	fair					1	distinct.
31	$4d$	$\bar{4}01$	$4\bar{P}\infty$	+	+	15 27	15 29	v.g.					3	large and smooth.
32	$\frac{8}{5}d$	$\bar{5}03$	$\frac{8}{5}\bar{P}\infty$	+		23 9	23 10	g.					1	fair, disturbed.
33	$\frac{5}{2}d$	$\bar{5}02$	$\frac{5}{2}\bar{P}\infty$		+	24 39	25 2	fair					1	narrow, distinct.
34	$2d$	$\bar{2}01$	$2\bar{P}\infty$	+		30 27	30 35 30 27 30 29	fair v.g. g.					3	large and smooth.

TABLE I (*continued*).

No.	Letter or Symbol.	Indices. Miller.	Indices. Naumann.	Crystal. No. 1.	Crystal. No. 2.	Angles to $a = 100$. Calculated.	Angles to $a = 100$. Measured.	Angles to $a = 100$. Value.	Angles to other faces. Face.	Angles to other faces. Calculated.	Angles to other faces. Measured.	Angles to other faces. Value.	Number of Measured Angles.	Remarks.
						° ′	° ′			° ′	° ′			
Orthodomes, positive (*continued*) :—														
													3	very narrow.
35	$\frac{9}{5}d$	905	$\frac{9}{5}\bar{P}\infty$	+	+	33 32	34 14	fair						
							34 0	do.					1	narrow, distinct.
							34 1	do.						
36	$\frac{8}{5}d$	805	$\frac{8}{5}\bar{P}\infty$	+		37 12	37 9	fair					1	small, distinct.
37	$\frac{3}{2}d$	302	$\frac{3}{2}\bar{P}\infty$		+	39 18	40 35	fair					1	very narrow.
38	$\frac{4}{3}d$	403	$\frac{4}{3}\bar{P}\infty$	+		43 17	43 27	ca.					3	very narrow.
39	$\frac{5}{4}d$	504	$\frac{5}{4}\bar{P}\infty$	+	+	45 32	45 43	fair					4	distinct and smooth.
							45 26	do.						
40	d	101	$\bar{P}\infty$	+	+	Fund.	53 25	v.g.					1	distinct, striated.
41	$\frac{19}{20}d$	$\overline{19}.0.20$	$\frac{19}{20}\bar{P}\infty$		+	55 14	55 22	fair					1	very narrow.
42	$\frac{7}{10}d$	7.0.10	$\frac{7}{10}\bar{P}\infty$	+	+	65 33	65 2	ca.					1	very narrow.
43	$\frac{2}{3}d$	203	$\frac{2}{3}\bar{P}\infty$			67 5	66 45	fair					2	narrow, striated.
44	$\frac{4}{7}d$	407	$\frac{4}{7}\bar{P}\infty$	+	+	71 40	71 55	fair						
							71 44	ca.					1	narrow, rough.
45	$\frac{3}{7}d$	207	$\frac{2}{7}\bar{P}\infty$		+	86 42	86 47	fair					1	narrow, distinct.
Orthodomes, negative :—														
46	$-4\,d$	401	$-4\,\bar{P}\infty$	+		13 52	13 34	fair					2	large, striated.
47	$-\frac{4}{3}d$	403	$-\frac{4}{3}\bar{P}\infty$	+	+	33 48	33 53	v.g.						
							33 51	fair					1	narrow, distinct.
						36 51	36 42	fair						

50	$-\frac{1}{12}d$	11.0.12	$-\frac{1}{12}\bar{P}\infty$	+		42 25	42 25	fair					3	large broad face, good.
51	$-\frac{3}{4}d$	304	$-\frac{3}{4}\bar{P}\infty$	+		46 55	46 1	ca.					1	narrow, striated.
52	$-\frac{2}{7}d$	207	$-\frac{2}{7}\bar{P}\infty$		+	63 45	64 20	fair					1	very narrow, indistinct.
Pyramids :—													1	distinct.
53	e	$\bar{1}11$	P	+	+	64 32	64 35 64 22	ca. fair	110	35 59	35 55 35 59	fair	2	small, distinct.
54	γ	$\bar{4}41$	4 P		+	52 12			110	9 36	9 42	g.	1	small, distinct.
55	ρ	113	$-\frac{1}{3}$ P		+	63 33			110	57 31	57 4	ca.	1	very small.
56	Δ	445	$-\frac{4}{5}$ P	+		54 36			110	36 42	36 48	g.	1	very small, distinct.
57	r	111	$-$P	+	+	52 59	52 59 53 2 53 3	g. ca. v.g.	110	31 19	31 20 31 8 31 26	fair g. g.	3	small, good.
58	m	443	$-\frac{4}{3}$ P		+	51 32			110	24 58	24 47 24 55 24 58	g. fair do.	3	small, distinct.
59	z	221	-2 P		+	50 32			110	17 36	17 9	ca.	1	very small, curved.
60	o	441	-4 P	+	+	50 20	50 29	g.	110	9 12	9 9 9 9	fair g.	3	small, distinct.
61	H	344 or 799	$\grave{P}\frac{4}{3}$ or $\grave{P}\frac{4}{11}$		+	72 7 71 14	71 7	ca.					1	small, narrow, distinct.
62	δ	$\bar{1}66$	$\grave{P}6$	+		92 5	92 3	ca.					1	very small.
63	u	$\bar{1}23$	$\frac{3}{2}\grave{P}2$	+	+	85 23			120	52 40	52 30 52 48	ca. ca.	3	very small.
64	ϵ	$\bar{2}45$	$\frac{4}{5}\grave{P}2$	+	+	83 6			120	47 3	47 1 47 3	fair v.g.	3	small, distinct.
65	h	$\bar{1}22$	$\grave{P}2$	+	+	80 25	80 6 80 24	g. g.	120	40 12	40 8 40 12	g. g.	3	large and distinct.
66	g	$\bar{2}43$	$\frac{4}{3}\grave{P}2$		+	77 20			120	31 56	31 54	g.	1	small, distinct.

TABLE I (*continued*).

No.	Letter or Symbol.	Indices. Miller.	Indices. Naumann.	Crystal. No. 1.	Crystal. No. 2.	Angles to $a = 100$. Calculated.	Angles to $a = 100$. Measured.	Angles to $a = 100$. Value.	Angles to other faces. Face.	Angles to other faces. Calculated	Angles to other faces. Measured.	Angles to other faces. Value.	Number of Measured Angles.	Remarks.
						° ′	° ′			° ′	° ′			
									120	22 14	22 14	g.	1	small, distinct.
67	β	$\bar{1}21$	$2\dot{P}2$		+	74 0			120	16 55	17 3	ca.	1	very small.
68	R	$\bar{4}83$	$\frac{8}{3}\dot{P}2$		+	72 22			120	11 22			1	narrow, distinct.
69	v	$\bar{2}41$	$4\dot{P}2$	+		70 48	70 41							large, distinct.
									120	36 43	36 44	ca.	2	very narrow.
70	p	122	$-\dot{P}2$	+		65 57	65 55	g.	120	31 7	30 31	ca.	1	very small,
71	A	5.10.8	$-\frac{5}{4}\dot{P}2$	+		65 36			120	29 34	29 33	fair	1	distinct.
72	μ	243	$-\frac{4}{3}\dot{P}2$		+	65 33							1	small, distinct.
73	q	241	$-4\dot{P}2$	+		66 24	66 58	g.	120	11 2	10 56	g.	1	very small, distinct.
74	x	$\bar{2}11$	$2\bar{P}2$		+	42 30	42 23	fair					1	small, distinct.
75	ν	211	$-2\bar{P}2$	+		36 9	36 6	g.					1	small, distinct.
									320	7 52	7 58	fair	1	very small,
76	D	$\bar{6}41$	$6\bar{P}\frac{3}{2}$		+	41 25			320	31 17	30 56	ca.	1	doubtful.
77	σ	645	$-\frac{6}{5}\bar{P}\frac{3}{5}$	+		45 21			320	20 47	20 35 21 8	g. ca.	2	large, distinct.
78	s	643	$-2\bar{P}\frac{3}{2}$	+	+	41 24			320	14 30	14 13	fair	1	small, distinct.
79	t	321	$-3\bar{P}\frac{3}{2}$	+		39 58			320	6 29	6 35	ca.	1	long and very narrow, curved.
80	Y	21.14.3	$-7\bar{P}\frac{7}{3}$		+	39 17								

TABLE I (*continued*).

81	τ	322	$\frac{3}{3}\bar{P}\frac{3}{2}$		+	51 54	51 48	v.g.	320	30 39	30 38	v.g.	1	large and smooth.
82	π	722	$\frac{7}{3}\bar{P}\frac{7}{2}$	+		26 24	26 32	ca.					1	very narrow.
83	η	611	$6\bar{P}6$	+		15 43	15 5	ca.					1	very narrow, doubtful.
84	n	322	$-\frac{3}{2}\bar{P}\frac{3}{2}$	+	+	43 18	43 22 43 23 43 13	v.g. fair g.	320	26 28	26 25 26 22	g. ca.	3	large, very good.
85	V	722	$-\frac{7}{2}\bar{P}\frac{7}{2}$	+		23 35	24 25	ca.					1	very small, doubtful.
86	N	411	$-4\bar{P}4$	+		21 3	21 47	ca.					1	very small, doubtful.
87	C	12.1.1	$-12\bar{P}12$	+		7 34	7 28	ca.					1	very small, doubtful.

Prisms, observed on other Crystals:

				No. 5.	No. 6.	No. 7.								
	$\frac{1}{2}\bar{1}f$	11.2.0	$\infty\bar{P}\frac{1}{4}\bar{1}$	+			12 46	12 56	ca.				1	very narrow, striated.
	$\frac{1}{6}\bar{1}f$	11.5.0	$\infty\bar{P}\frac{1}{6}\bar{1}$			+	29 32	29 28	fair				1	narrow, distinct.
	$\frac{5}{4}\bar{f}$	540	$\infty\bar{P}\frac{5}{4}$		+	+	44 55	44 48	v.g.				2	broad, good.
	$4\grave{f}$	140	$\infty\grave{P}4$	+		+	78 40	78 36	g.				2	broad, good.

traversed, exactly as in No. 1, with many twin-lamellae parallel to a (100), of which the most prominent are indicated in fig. 3 by dotted lines. The prism-faces were also smooth and brilliant, but very small and repeated, thus obscuring the zones, which were so clear and prominent in No. 1. The monoclinic habit was, however, quite evident, and the twinned nature clearly indicated by the reentrant angle of the basal pinacoids. On account of the inferior development of leading planes, it was found impossible to unravel this crystal, until the complete calculations on No. 1 had been made, and all its faces determined; it was then found that the three zones [*ueh*], [*for*], and [*nrh*] agreed in their angles with those of No. 1. Thereupon the best reflections, viz. those from the faces h and f, were utilized as a foundation for the determination of the observed faces, with the result shown on Table I, in which the measured angles agree fairly well with the calculated ones.

As is indicated in fig. 3, this crystal consists of three individuals, attached to each other on the face a (100) as twin-plane, in such a manner that the central individual appears inserted as a broad twin-lamella between the two exterior ones. The twinning edge is clearly developed in the upper half of the crystal between I on the right hand and II, but in the lower part, and between I on the left and II, is obscured, partly by fracture and partly by a very small protruding crystal in the position I. The faces h, ϵ, u and h, $\underline{\epsilon}$, $\underline{u}$ give respectively the following (non-reentrant) angles:

$h : \underline{h}$	calculated	19°10′,	observed	19°12′
$\epsilon : \underline{\epsilon}$	„	13°47′	„	14°14′
$u : \underline{u}$	„	9°15′	„	10° 1′
$c : \underline{c}$	„	24°24′	„	24°11′

Fig. 4 is meant to represent this crystal in an ideal development, with the principal forms observed on it.

It will be noticed that the clinodomes are totally absent, and that there is a richer development of the positive hemipyramids as compared with crystal No. 1: we find 12 of them, as against 8 on No. 1, and 9 negative hemipyramids corresponding with 14 on No. 1. It is very strange that only eight pyramids are common to both crystals, viz. e, r, o, u, ϵ, h, s, and n, which, however, represent those with simpler indices, and belonging to the principal zones. This feature seems to be of some significance: for if such widely different sets of related forms are found on two crystals, which were originally attached to each other

and probably in twinned position, then it might be expected that still wider differences would be observed on crystals from other specimens: and this may in part explain the want of agreement between the observations made on different crystals of sartorite by other investigators.

On my crystals Nos. 1 and 2 other pyramidal faces could be detected, but they defied measurement on account of their minute size, or their hidden position. In fig. 5 almost all the forms observed on crystals Nos. 1 and 2 have been represented in a stereographic projection on the plane of symmetry.

The most important question which arises out of the above observations, is whether these crystals are actually sartorite or whether they belong to some other mineral. The crystals are so small that any chemical test is out of the question; so also is a determination of the specific gravity. A distinct cleavage was nowhere observable on any of the crystals examined by me. The only means of identification remaining are the geometrical form and the streak. The latter was examined on minute fragments from crystals Nos. 1, 2, 5, and 6, and found to be practically the same with all of them, viz. reddish-chocolate, in harmony with the statement of vom Rath. On the other hand, a very similar streak is given by the related minerals dufrenoysite, rathite, and baumhauerite, so that this character is not much to be relied upon.

With respect to the geometrical form there is already a considerable diversity between the forms given by vom Rath and by Baumhauer, especially, as has been pointed out by the latter, among the macrodomes (see l. c., p. 249). On the other hand, four of the five brachydomes observed by vom Rath are repeatedly observed again by Baumhauer. On the seven crystals, which I have examined, the measurements of the orthodomes show so little similarity that I have found it impossible to harmonize them either with each other, or with those observed by vom Rath and Baumhauer. Even between the crystals Nos. 1 and 2 there is so little similarity, notwithstanding the fact that these two crystals undoubtedly belong to the same larger one, and are of the same substance, that only five positive and two negative hemiorthodomes, out of a total of twenty-six, appear on both of them.

On the crystals Nos. 3 and 4, notwithstanding the exceptionally perfect development of the prism-zone and the orthopinacoids, the orthodomes could not be determined at all, for the whole zone of these, on both crystals, gave a continuous series of grouped reflections, due to the fine striation, so that not a single individualized reflection could be noted. The crystals Nos. 5, 6, and 7 gave some very satisfactory

reflections, but in no case could they with certainty be brought into harmony with the orthodomes observed on Nos. 1 and 2; even on one and the same crystal, what appeared to be corresponding faces gave very variable angles. The impression conveyed is that the faces of this zone are profoundly influenced by repeated twinning or some other as yet unexplainable cause.

Only in the prism, or brachydome, zone of all hitherto described crystals is there found an unexpected and striking similarity, which I have attempted to show on the comparative Table II. It contains the whole of the brachydomes given by vom Rath and Baumhauer and all the prisms observed on my crystals Nos. 1 to 7, together with the calculated and the principal measured angles. It will be at once noticed that the forms most frequently observed by me correspond in the angles with those most often observed by the above-named authors, and that there exists a fairly close agreement between the measured and calculated angles.

In Table III I have furthermore tabulated, for the four most frequent prisms, all my best measurements, in order to indicate the fluctuations on one and the same and on different crystals. A comparison of these results with each other and with previous observations would seem to justify the assumption that all my seven crystals actually belong to the mineral sartorite.

On the crystals Nos. 3 and 4, there was no indication of the presence of any pyramidal faces. No. 7, a well-formed crystal of the ordinary type, showed a few rounded indeterminable pyramids. Crystals No. 5 and 6 were derived from a very small specimen of dolomite, and represent the upper and lower terminations of one and the same somewhat larger crystal, the central portion of which was overlaid by a similar one, almost at right angles to it, such as has been referred to by Baumhauer (l. c., p. 251) as being possibly a twin-formation. This rectangular intergrowth of sartorite is a not uncommon occurrence. Both of these crystals have a rich development of pyramidal faces, of which forty-five were counted on No. 5 and about thirteen on No. 6. Twin-lamellae were distinctly observable on both crystals, but especially on No. 6, where some of the faces were quite devoid of them, and others were closely intersected. The zonal relations of these pyramidal faces were, however, so indistinct, and most of them were so small, that it has not been possible so far to identify them. Some measurements made on crystal No. 6 could not be harmonized with Nos. 1 and 2, nor with the pyramids observed by Baumhauer.

Symbol.		v. Rath & Baumh.		C.O.T.		Observed by		Number of measured edges.	C O.T. observed on Crystal No.							Number of measured edges.
C.O.T.	v. R. & B.	to $c = 001$.		to $a = 100$.					1	2	3	4	5	6	7	
		Calculated.	Observed	Calculated.	Observed.	v. R.	B.									
$20\bar{f}$				3° 34′	3° 34′											
$\frac{1}{2}\bar{f}$	$1\frac{4}{1}f$	12° 41′	12° 38′	12 46	12 56		+[3]	2		+						1
$5\bar{f}$	$\frac{5}{2}f$	13 54½	14 2	14 0	14 2		+	2		+			+			1
$\frac{9}{2}\bar{f}$	$\frac{9}{2\,0}f$	15 34	15 29	15 29	15 29		+	1	+	+					+	3
	$\frac{7}{1\,5}f$	16 7	16 5				+	1 uncertain	+						+	2
$4\bar{f}$	$\frac{1}{2}f$	17 12	17 16	17 19	17 8		+[3]	2	+							
$\frac{7}{2}\bar{f}$	$\frac{4}{7}f$	19 28	19 30	19 36	19 32		+	1	+[2]				+	+[3]	+	2
$3\bar{f}$	$\frac{3}{5}f$	22 25	22 24	22 34	21 35		+[3]	2		+						5
$1\frac{1}{4}\bar{f}$				24 23	24 38					+						1 uncertain
$\frac{8}{3}\bar{f}$	$\frac{4}{5}f$	26 20	26 10-20	26 30	26 30		+	2	+[2]		+[4]	+	+[3]	+[3]	+	1
	$\frac{5}{6}f$	27 17	27 6				+	1 uncertain								12
$\frac{9}{4}\bar{f}$				28 59	29 0				+							
$1\frac{1}{5}\bar{f}$				29 32	29 23											1
	$1\frac{4}{1\,5}f$	30 0	30 1				+	1							+	1
$2\bar{f}$	f	31 45	31 54	31 56	31 54	+	+	3	+	+						
$1\frac{1}{7}\bar{f}$				38 26	38 18					+				+		3
$\frac{9}{4}\bar{f}$	$\frac{4}{3}f$	39 31	39 41	39 44	39 44-48	+	+	5	+[2]	+	+[4]	+	+	+[1]	+	1
	$4\frac{1}{3\,5}f$	40 14	40 15				+	1								12
$\frac{4}{3}\bar{f}$	$\frac{3}{2}f$	42 52	43 28	43 5	42 55	+		1		+			+	+		
	$\frac{4\,7}{3\,0}f$	44 7	44 18				+	1 uncertain								3
$\frac{5}{4}\bar{f}$				44 55	44 48											
	$1\frac{7}{1\,0}f$	46 27	46 32				+	1 uncertain						+	+	2
	$2\frac{6}{1\,5}f$	47 1	47 6				+	1								
	$2\frac{9}{1\,5}f$	50 7	50 3-6				+	2								
f	$2f$	51 4	51 10-14	51 16	51 16	+	+[5]	7	+[3]	+	+[4]	+[2]	+[2]	+	+[2]	14
$2f$	$4f$	68 0	68 4	68 9	68 2-10	+	+[6]	8	+[2]	+	+[4]	+[2]	+[2]	+	+[2]	14
$3f$				75 2	75 48					+						1 uncertain
$4f$				78 40	78 36								+		+	2
$1\frac{3}{5}f$				82 58	82 56				+							1
b	010	90 0	90 0	90 0	90 0	+	+	2	+		+[2]	+	+		+	6

TABLE III.—Fluctuations of the Angles of the Principal Prisms.

Angles to $a = 100$.										
Symbol.	Indices.			Measured on Crystal No.						
	Miller.	Naumann.	Calculated.	1	2	3	4	5	6	7
			° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
$\frac{6}{2}\bar{f}$	520	$\infty \bar{P} \frac{6}{2}$	26 30	26 30½ 18		26 25 26 16½ 37½	26 25½			26 24
$\frac{3}{2}\bar{f}$	320	$\infty \bar{P} \frac{3}{2}$	39 44	39 48	39 44	39 38 38½ 17½ 46	39 34½		39 34	39 36
f	110	∞ P	51 16	51 16½ 15½	51 8	51 9½ 13½ 4 21½	51 6	51 7	51 6½	51 8 6½
$2\grave{f}$	120	$\infty \grave{P} 2$	68 9			68 10½	68 1½ 5¾	68 8		68 2½ 2½

It may be mentioned that in the determination of the orthodomes of Nos. 1 and 2 only distinct and individualized reflections were made use of; all such as were grouped or coloured were rejected, or only used to corroborate better reflections. All the measurements were made on a Fuess No. 2 horizontal-circle goniometer, with the eyepiece γ, a small angle of incidence, and a Websky slit illuminated by an incandescent gas-lamp and the condensing lens. Even the smallest pyramidal faces, owing to their brilliancy, gave distinct and individualized reflections, and may, therefore, with few exceptions, be considered as safely determined.

With less confidence would I wish it to be assumed that the crystals Nos. 1 and 2 are, beyond any doubt, to be considered as sartorites. It is not impossible that we have here to deal with a case similar to that of the humite group, in which several closely allied substances possess identical or almost identical angles in one zone, and different ones in the zone perpendicular to the first. It is also possible that such morphotropic substances may form lamellar intergrowths, and thus obscure the crystallographic properties of each other. An apparent lamellar structure is observable on fractured surfaces of sartorite, and is also visible on crystals Nos. 1 and 2.

Further observations are necessary in order to clear up the difficulties and discrepancies still attaching to even the most perfect crystals of this mineral, and it is hoped that this contribution may draw renewed attention towards it.

Explanation of Plate V.

Crystals of Sartorite from the Binnenthal, Switzerland.

Orthogonal projections on the plane of symmetry. (The dotted lines represent twin-lamellae parallel to a (100).)

Fig. 1.—Crystal No. 1; actual development.

Fig. 2.—The same; ideal development.

Fig. 3.—Crystal No. 2; actual development of twinned crystal.

Fig. 4.—The same; ideal development.

Fig. 5.—Stereographic projection on the plane of symmetry, showing most of the forms observed on crystals Nos. 1 and 2.

Notes on skiodroms and isogyres.

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[Read June 12, 1906.]

PROFESSOR BECKE'S paper[1] on skiodroms marks an important advance in our knowledge of the shadows, or isogyres, which are seen when sections of crystals are examined in convergent polarized light. The isogyres can also be advantageously studied in mineral grains, where the irregular shape disturbs the distribution of the interference colours, but has much less effect on the shadows due to the coincidence of directions of vibration in the crystal with those of one of the nicols.

Throughout Professor Becke's communication[2] the movements of these dark bars or brushes are described as they are seen in a microscope where the stage rotates and the nicols are fixed, such as is almost invariably used in Germany. The fact that the section is not fixed relatively to the field of the microscope is a serious disadvantage, for the movement of the stage is superposed on that of the shadows relatively to the fundamental optical directions of the crystal, so that it is somewhat difficult to realize the true nature of the latter movement.

If, however, a microscope with fixed stage and revolving nicols be employed, the optical directions remain unchanged in position and the whole investigation is simplified, so that the variations in form and position of the shadows, or isogyres, as the nicols rotate, and their connexion with the skiodroms can be easily followed. With rotating nicols there is no difficulty in sketching under a camera-lucida, not only different positions of the isogyres, but also the forms of the skiodroms in the section under examination.

I shall accordingly concisely describe and explain the shadow phenomena seen in a microscope with a fixed stage and revolving nicols and, as in the abstract (p. 278), shall for brevity's sake confine myself to

[1] 'Die Skiodromen. Ein Hilfsmittel bei der Ableitung der Interferenzbilder.' Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1-34; abstracted on p. 276 of this volume.

[2] Except for a brief allusion on p. 12.

sections which do not show an axis of optical symmetry or an optic axis, though the same principles may easily be extended to such cases.

In oblique sections of uniaxial crystals the longitudinal skiodroms (which are here meridian) converge towards the optic axis. They are at the same time slightly concave to the straight longitudinal skiodrom that passes through the centre. As the nicols are rotated, the isogyre moves across the field approximately in the same manner as if it were rotating with the angular velocity of the nicols about the optic axis, but the end further from the optic axis moves slightly faster than if that were the case—a result of the curvature of the lateral longitudinal skiodroms.

The terms homodrom and antidrom are now no longer applicable, as the end nearer the optic axis (the so-called homodrom end) moves round the circumference of the field in the opposite angular direction to that in which the nicols rotate, while the end further from the optic axis (the antidrom end) moves round with the nicols. I, therefore, propose to employ the epithet 'proximal' for the end of the isogyre and the margin of the field nearer the optic axis, and 'distal' for those directed away from it. The same terms may be employed by analogy in the case of biaxial crystals. The margin of the field and the end of the isogyre on the side towards which the longitudinal skiodroms converge will be proximal, and those on the opposite side will be distal. Here, too, the proximal end of the isogyre moves round the circumference of the field in an angular direction contrary to that in which the nicols revolve, and the distal end in the same direction as the nicols. (See figs. 3 and 6.)

In sections whose normal lies in the optic axial plane of a biaxial crystal the disposition of the skiodroms and movement of the isogyres present considerable resemblance to those in an oblique section of a uniaxial crystal. The lateral longitudinal skiodroms converge in the direction of the nearest optic axis, which therefore lies on the proximal side of the field. They are markedly concave towards the central skiodrom and accordingly make a less angle with it on the distal margin than on the proximal. The distal end of the isogyre therefore moves with much greater velocity than the proximal end, and when it reaches the periphery of the field it is strongly curved outwards. The pendulum motion is much more vigorous than when the stage, and not the nicols, rotates. (See figs. 1–3.)

In sections whose normal lies in a plane of optical symmetry, including a bisectrix and the optic normal, the longitudinal skiodroms converge towards the bisectrix, but they are convex towards the central

skiodrom and are therefore more inclined to it on the distal than on the proximal side of the bisectrix. The proximal end of the isogyre therefore moves faster than the distal end, but this character is less marked than when the stage rotates instead of the nicols. (See figs. 4–6.)

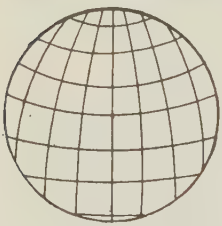
Fig. 1.

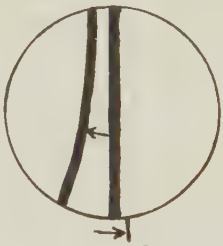
Fig. 2.

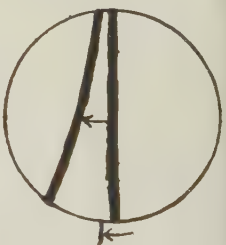
Fig. 3.

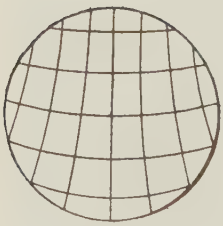
Fig. 4.

Fig. 5.

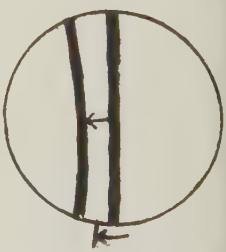
Fig. 6.

Explanation of Figures.

Fig. 1.—Skiodrom-net for a section whose normal lies in the optic axial plane.

Fig. 2.—Movement of the isogyre in such a section when the *stage* is rotated anticlockwise.

Fig. 3.—Movement of the isogyre in the same section when the *nicols* are rotated through the same angle clockwise.

Fig. 4.—Skiodrom-net for a section whose normal lies in a plane of optical symmetry passing through a bisectrix and the optic normal.

Fig. 5.—Movement of the isogyre in such a section when the *stage* is rotated anticlockwise.

Fig. 6.—Movement of the isogyre in such a section when the *nicols* are rotated clockwise.

Figs. 2, 3, 5, and 6 each show two positions of the isogyre: (i) the central position parallel to one of the nicols, and (ii) that after rotation of the stage or nicols through an angle equal to that between the lower end of the central isogyre and the short line across the point of the arrow below the circle.

Figs. 1 and 4 are copied from Professor Becke's paper. Compare figs. 1 and 2 on p. 277 of this volume.

If the section-normal does not lie in a plane of optical symmetry, the movement of the isogyre will be essentially similar to one of the types already described, but the movements, like the skiodroms, will be asymmetrical.

There is another point of nomenclature in which I would suggest a change. The use of the expression α- or γ-ellipses is open to misconception, as α properly denotes the minimum and γ the maximum index of refraction in the crystal. I would prefer to speak of fast and slow ellipses, or skiodroms, and of a section where the longitudinal skiodroms are fast or slow as having a fast or slow instead of a positive or negative reaction.

Professor Becke's rule for determining the sign or character of the reaction of a section may be easily employed in a microscope with rotating nicols. The nicols are rotated till the isogyre passes through the centre of the field. The cross-wire that is parallel with the isogyre at the centre, or makes an angle of less than 45° with it, is taken as the geographical meridian and the direction of the proximal margin as the north; the rule will then be applied exactly in the same manner as stated in the abstract (p. 279).

In some cases, especially if the rate of change of the relative retardation from point to point in the image in convergent light be very great, it is difficult to apply the Becke rule. It is then better, after ascertaining the direction of the longitudinal skiodrom at the centre (which is that of the cross-wire parallel to the central isogyre, or making with it an angle less than 45°), to rotate the nicols through 45° and to determine by means of the quartz-wedge in parallel light whether the vibrations parallel to the longitudinal skiodrom are faster or slower than those at right angles to it.

The direction of the cross-wire which is parallel to the central isogyre, or makes an angle of less than 45° with it, may be conveniently referred to as the longitudinal extinction, and that at right angles to it as the transverse extinction. These extinctions may also be referred to as fast or slow, according as they are parallel to the fast or slow vibrations. If, then, the longitudinal extinction be fast or slow, the reaction of the section will have the same character.

There are some sections in which the isogyre is so ill-defined that it is difficult or impossible to determine the direction of the longitudinal skiodroms. This may be due to the fact that the section-normal is too far removed from the optic axial plane, or to strain or other optical abnormalities. In such cases it is useful to remember that the proximal

margin of the field is that which shows the lowest relative retardation or 'colour'; for the birefringence diminishes as the optic axes are approached, and with an objective of any ordinary aperture the greater length traversed in the crystals by light in the periphery of the field is not sufficient to counteract the decrease in the birefringence. The portion of the field in which the relative retardation is least may be roughly ascertained by rotating the nicols through 45° from the position of extinction in parallel polarized light, and inserting a gypsum-plate over the image in convergent light. The region of the lowest relative retardation is that in which the colour approximates most nearly to that of the plate when inserted alone [1].

This method is not applicable where the relative retardation is very high; it is then necessary to use a quartz-wedge inserted in the focus of the eyepiece in convergent light under the same conditions as those just mentioned for the gypsum-plate. The coloured bands will then usually be curved or inclined. If the wedge be in the position of compensation, the bands will, where the relative retardation is less, be advanced nearer to the thin end of the wedge. If, on the other hand, the wedge be in the additive position, the bands will, where the birefringence is less, be retracted towards the thick end. By inserting the wedge in parallel light, first in one direction of extinction and then in the other, it is possible to determine the portion of the periphery where the relative retardation is lowest; this will be the direction of the proximal end of the central longitudinal skiodrom. The same observation will also have determined whether this is the direction of the faster or slower vibration, and what is the sign or character of the reaction of the section.

Mr. H. Hilton's paper [2] on the application of the gnomonic projection to isogyres in the neighbourhood of the centre of the field, recalls an unpublished suggestion of my own; namely, that, with a view to using the same projection, an objective with a plane focal surface for light from infinite distance should be employed. I find on inquiry that objectives practically satisfying this condition are already manufactured in this country.

[1] The use of the gypsum-plate in this way to determine the direction of the acute bisectrix in a section at right angles to the optic normal was first introduced by Professor Becke, Min. Petr. Mitt. (Tschermak), 1897, vol. xvi, p. 181.

[2] Zeits. Kryst. Min., 1906, vol. xlii, p. 277; abstract in this vol., p. 281.

Communications from the Oxford Mineralogical Laboratory. No. VIII.

On the regular growth of soluble salts on each other.

By Thomas Vipond Barker, B.A., B.Sc. (Oxon.)
Senior Demy of Magdalen College, Oxford.

[Read November 13, 1906.]

PREVIOUS work on the regular growth of crystals of salts on those of Minerals belonging to the same isostructural series led the author [1] to the discovery that parallel deposition is conditioned by closeness, not of angle nor of axial ratios, but of molecular volume. Now although the substances previously examined resemble each other crystallographically, yet they exhibit such great differences in chemical properties, that reasonable doubt might be entertained whether conclusions drawn from them can be directly applied to isomorphous substances; and it therefore became advisable to extend the observations to a group of the latter.

The group selected should, from the nature of the problem, not only be numerous but should also exhibit great differences of molecular volume amongst its members. Now the largest isomorphous group known is that of the double sulphates and selenates, which has been so thoroughly investigated by Tutton; this group, however, like that of the alums, does not fulfil the second condition, for the range of molecular volume is comparatively small: this results from the high molecular weight associated with the relatively small amount of chemical substitution. A suitable group is met with in the chlorides, bromides, iodides, and cyanides of sodium, potassium, rubidium, caesium, and ammonium, which crystallize in the cubic system; further, the majority of the salts possess a perfect cubic cleavage, so that there is no difficulty in obtaining clean surfaces.

Of the above salts, rubidium and caesium cyanides have not been

[1] T. V. Barker, 'Contributions to the theory of isomorphism based on experiments on the regular growths of crystals of one substance on those of another.' Journ. Chem. Soc. Trans., 1906, vol. lxxxix, pp. 1120-1158.

previously described; but, although the published crystallographic data concerning the remaining salts leave little to be desired individually, yet great uncertainties exist with regard to their relationships as a whole. Thus, ammonium chloride and bromide cannot be obtained in cubes without the addition of other substances—especially urea—to their solutions, and the crystals so obtained exhibit only a very poor cleavage: the miscibility, again, of some of the pairs investigated is vanishingly small: finally, etching experiments point to a difference of symmetry. For the above reasons, strict isomorphism has been denied, and evidence for at least dimorphism has been adduced by Lehmann, Groth, and others.

It might therefore seem that a careful investigation of the group was imperative before carrying out experiments on parallel growths. But the latter have been taken in hand first, in order to see whether they can afford a new way of exploring the inter-relationships of the members of a group, concerning which most divergent opinions have been held.

Experimental.

I. Preparation and analyses of the salts.

The chlorides, bromides, and iodides of rubidium and caesium were mostly purchased from Merck, small quantities of some of them being also made by double decomposition of the metallic sulphate and the halogen salt of barium. Potassium and barium cyanides were purchased from Kahlbaum, and, setting out from the latter, rubidium and caesium cyanides were made by double decomposition. The remaining salts were the chemically pure salts of commerce. Several attempts were made to bring ammonium cyanide into the scope of this inquiry, but were unsuccessful owing to the instability of this compound. The cyanides of caesium and sodium were prepared, but it was found impossible to use them, owing to the difficulties encountered in obtaining good crystals.

Sodium bromide and iodide crystallize with two molecules of water at ordinary temperatures in monoclinic plates, but at higher temperatures anhydrous cubes are formed. It was found possible to isolate cubes of sodium bromide of sufficient size above a temperature of 60° C., so the growths on these cubes were investigated. Anhydrous cubes of sodium iodide are more difficult to obtain, a higher temperature being necessary, and they are difficult to isolate owing to their great deliquescence; on this account it was found impossible to use them in the experiments on parallel growths. Sodium cyanide crystallizes at ordinary temperatures

in monoclinic plates—apparently isomorphous with the hydrated bromide and iodide—which are probably the compound $NaCN . 2H_2O$ obtained by Joannis[1] from an alcoholic solution. At slightly higher temperatures, anhydrous cubes are formed. Sodium chloride separates out in monoclinic plates with two molecules of water below $-10°$ C. (Mitscherlich). We therefore see that all the four sodium salts appear in two modifications, one anhydrous at higher temperatures, the other hydrated at lower temperatures; the transition temperatures approximately lie at $-10°$ C. for sodium chloride, 50° C. for sodium bromide, 65° C. for sodium iodide, and 30°.C. for sodium cyanide.

The analysis of rubidium cyanide consisted in a cyanogen determination by precipitation with silver nitrate, the silver cyanide being dried and weighed—

0·4555 gram gave 0·4799 gram AgCN; CN = 23·00 per cent.
(RbCN requires 23·37 per cent.)

The specific gravities of potassium and rubidium cyanides were determined by the suspension method, the suspension fluid employed being a mixture of methylene iodide and benzene; only the clearest splinters were used.

Potassium cyanide: two determinations with independent material gave a mean value

Sp. gr. (17°/4° C.) = 1·578.

Rubidium cyanide: three determinations gave a mean value

Sp. gr. (21°/4° C.) = 2·295.

Determinations of the solubility of potassium cyanide and the specific gravity of the solution were made—

100 parts water dissolve 81·3 parts KCN at 13° C., and the specific gravity of the saturated solution is

Sp. gr. (13°/4° C.) = 1·2220.

II. Crystalline form and habit of the salts.

Some of the salts yield fine, clear cubes from the pure aqueous solution, while others can only be obtained in clear crystals by the addition of other substances to the solution. The following is an account of the various salts:—

Sodium chloride.—Cubes of a sufficient size are difficult to obtain, so most of the experiments on parallel growths were made with rock-salt

[1] Ann. Chim. Phys. 1882, ser. 5, vol. xxvi, p. 484.

from Galicia. Retgers[1] obtained good cubes by the addition of various substances to the solution, e.g., K_2CO_3, HCl, $FeCl_3$, $CuCl_2$, NaOH, &c.; the author found the last of these to give the best results.

Potassium chloride.—This tends to form skeletal growths, but good crystals were obtained from solutions containing 1 per cent. of KOH.

Potassium bromide and iodide; ammonium iodide; rubidium chloride, bromide, and iodide; potassium and rubidium cyanides; sodium bromide (above 60° C.).—The pure solutions of all these salts gave good cubes.

Ammonium chloride and bromide crystallize in skeletal forms, which are combinations of {211} and {110} (Tschermak, Slavík). Retgers (loc. cit.) showed that the presence of urea—which induces an octahedral habit in sodium chloride—favours the formation of simple cubes. These observations were repeated by Krickmeyer[2], who failed to obtain good cubes of ammonium bromide. The author finds that far more urea is required with ammonium bromide than with ammonium chloride; in fact the solution must contain great excess of urea, and by this precaution large cubic crystals of a yellowish tinge are obtainable by slow evaporation over sulphuric acid. The cubes of ammonium chloride attain a considerable size — up to 3 cubic centimetres; the crystals of ammonium bromide are somewhat smaller. Analyses were made in order to see whether the crystals contain urea:—

0·1931 gram AmCl gave 0·5160 gram AgCl, corresponding to 99·75 per cent. AmCl.

0·2400 gram AmBr gave 0·4562 gram AgBr, corresponding to 99·18 per cent. AmBr.

Since the crystals contained many inclusions of the mother-liquor, the above analyses prove that the crystalline material is practically free from urea; the crystals are very tough and the cubic cleavage is very imperfectly developed.

Although Sprockhoff[3] obtained good crystals of the caesium salts, the author has not been able to get large enough crystals for the study of parallel growths, so that the caesium salts have only been used as solutes.

III. Volume constants.

The halogen salts have been repeatedly investigated, and quite recently they have been the subject of an elaborate research by Sprockhoff (loc.

[1] Zeits. physik. Chem., 1892, vol. ix, p. 267.
[2] Zeits. physik. Chem., 1896, vol. xxi, p. 71.
[3] Neues Jahrb. Min., 1904, Beilage-Band xvi, p. 121.

cit.), so that it was not necessary to make any specific gravity determinations. Below is a table giving the molecular weight, specific gravity, and molecular volume of all the substances used in this investigation. The sources of the values of the specific gravities are given in brackets, and the atomic weights are those recommended by the International Committee for 1906, O = 16.

Table of Volume Constants.

Salt.	Molec. wt.	Sp. gr.	Molec. vol.
NaCl	58·50	2·173 (Gossner)[1]	26·92
NaBr	103·01	3·198 (Favre and Valson)[2]	32·21
NaI	150·02	3·654 („ „)	41·06
KCl	74·60	1·990 (Sprockhoff)[3]	37·49
KBr	119·11	2·751 („)	43·30
KI	166·12	3·131 („)	53·06
KCN	65·19	1·578 (Barker)	41·31
RbCl	120·95	2·806 (Sprockhoff)	43·10
RbBr	165·46	3·356 („)	49·30
RbI	212·47	3·564 („)	59·62
RbCN	111·54	2·295 (Barker)	48·60
CsCl	168·35	3·994 (Sprockhoff)	42·15
CsBr	212·86	4·452 („)	47·81
CsI	259·87	4·539 („)	57·25
AmCl	53·52	1·531 (Gossner)	34·96
AmBr	98·03	2·256 (Slavík)[4]	43·45
AmI	145·04	2·501 („)	58·14

The specific gravity determinations of the rubidium and caesium haloids made by Setterberg[5] agree well with the above values of Sprockhoff.

IV. Experiments on parallel growth.

The method of observation was extremely simple; a drop of a solution of one salt was placed on a fresh cleavage-piece of the other, which was viewed—on a glass-slide—under the microscope. Crystals of the solute appear as a rule in a few seconds, but the deposition is sometimes so rapid that the surface of the cleavage-flake becomes opaque instan-

[1] Gossner, Zeits. Kryst. Min., 1903, vol. xl, p. 70.
[2] Favre and Valson, Compt. rend. Acad. Sci. Paris, 1873, vol. lxxvii, p. 579.
[3] Sprockhoff, loc. cit.
[4] Slavík, Zeits. Kryst. Min., 1902, vol. xxxvi, p. 271.
[5] Öfvers. k. Vet.-Akad. Förh. Stockholm, 1882, vol. vi, p. 23.

taneously ; when this happened the solution was diluted a little, but even then, with certain pairs of salts, the deposition was so dense as to prevent the attainment of a positive result. Another difficulty also arises where the solubility is far greater for the crystal than for the solute, because the crystal then dissolves rapidly and the crystals deposited by the solute stream down the sides of the 'mother-crystal' and come to rest on the glass-slide.

Sometimes the cleavage-piece was heated while the deposition was going on. By varying the conditions of experiment, definite conclusions were finally arrived at with the great majority of the possible pairs of substances.

The following is a detailed account of the experiments :—

Sodium Chloride.—The material used was rock-salt from Galicia ; it contained many fluid-inclusions in the form of negative crystals.

KCl gave opaque cubes with somewhat imperfect outlines ; KBr, KI, and KCN crystallized out in cubes with sharp outlines ; RbCN in flowery cubes—the deposition of all these salts being parallel with the rock-salt. RbCl deposited crystals very similar to those of KCl, which were often parallel, but generally irregular[1] ; many attempts were made to decide one way or the other, but unsuccessfully. As the growths of sodium chloride on RbCl are parallel, it may be concluded that the deposition of RbCl on NaCl is really parallel. None of the remaining salts—except NaBr and NaI which are hereafter mentioned in a separate sub-section—gave a regularly orientated deposition : of these RbBr, RbI, AmI, AmCl, and AmBr, from solutions containing urea, gave well-defined cubes ; CsCl and CsBr gave petal-like forms ; CsI, AmCl, and AmBr, from their pure solutions, yielded rods.

Sodium Bromide.—Cubes were obtained from aqueous solution above 60° C.

KI, RbI, RbBr, and RbCl gave beautiful parallel cubes, as did also probably CsCl, but it is impossible to say with certainty owing to the rapidity of the deposition ; the character of the deposition of KCN, RbCN, AmI, and CsBr could not be made out for the same reason. Streams were immediately set up with NaCl, KCl, KBr, AmCl, and AmBr ; CsI gave irregular growths of cubes and dodecahedra.

Potassium Chloride.—The crystals were obtained from a solution containing a little potash.

[1] The term *irregular* does not mean that the outlines of the crystal were ill-defined, nor does it mean that the crystals do not belong to the regular system ; throughout this paper it is consistently used to denote *not parallel*.

NaCl gave cubes traversed by two diagonal bands: they are apparently made up of an immense number of small parallel cubes; KBr, RbCl, RbBr, KCN, and RbCN gave fine cubes: all the above were parallel. AmBr, with or without the addition of urea, gave a zonal growth or layer-crystal (Schichtkrystall): in other words the solution evaporates away without the formation of any separate, visible crystals in parallel position, but an even layer of crystalline material is spread over the whole cleavage-surface of the mother-crystal. (For a discussion of zonal growths see p. 252.) The remaining salts crystallized in the characteristic forms noted above under sodium chloride, but without any recognizable regularity.

Potassium Bromide.—Crystals were obtained from pure aqueous solution.

NaCl, KCl, and AmI immediately gave dense deposits of parallel cubes; the crystallization was slower with KI, RbBr, RbI, and RbCN, which yielded beautiful cubes in parallel position. But, in addition, AmCl and CsCl, which usually crystallize in rods or fronds, came down in parallel cubes. A zonal growth was afforded by KCN and RbCl, but on warming the latter slightly delicately fine, parallel cubes were obtained. The remaining salts were irregularly orientated: CsCl crystallized in petals; CsI in rods and dodecahedra.

Potassium Iodide.—Cubes were obtained from aqueous solution.

Parallel deposits of cubes were obtained with NaCl, RbCl, RbBr, AmCl, AmBr, KCN, KBr, and RbI, the two last salts coming down copiously. Nothing definite could be arrived at with KCl, owing to the rapid dissolution of the mother-crystal with subsequent streaming. AmI did not produce any separate crystals, but a zonal growth was formed. CsCl, CsBr, and CsI crystallized irregularly in rods.

Potassium Cyanide.—Obtained as cubes by slowly cooling a hot, aqueous solution.

KI and AmI gave parallel cubes; KCl gave a fine deposit, but parallel cubes grew out from the sides of the crystal, whilst RbCl formed a zonal growth. Dense deposits were immediately given by NaCl, KBr, AmCl, AmBr, CsCl, and CsBr, which excluded further investigation; RbCN gave some parallel cubes on heating. With RbBr the deposition, even with dilute solutions, was too rapid to enable one to judge whether it was parallel or no; finally CsI gave irregular rods.

Rubidium Chloride.—Obtained as cubes from aqueous solution.

Parallel deposits of cubes were afforded by CsBr and RbCN, and also, as a rule, by NaCl, whilst RbI and AmI gave cubes in irregular positions.

A zonal growth was formed with KBr and with KCN, but the latter gave a parallel deposition of cubes on heating; nothing could be deduced from the growth of KCl, KI, and RbBr owing to the rapid precipitation. AmCl and AmBr crystallized in irregular positions, in cubes or fronds, according as urea was present or absent; CsCl yielded irregular petals, and CsI, on heating, irregular rods.

Rubidium Bromide.—Obtained as cubes from aqueous solution.

Parallel cubes were deposited from solutions of KI, RbI, AmI, KCl, KBr, and RbCl, and the deposition of the three last salts was particularly dense; the cubes of NaCl, on the other hand, were irregular. The floral crystals of CsCl, and the rods of CsBr, CsI, and AmBr, together with the fronds of AmCl, had no definite orientation. A very finely divided deposit was given by KCN, but RbCN afforded a zonal growth.

Rubidium Iodide.—Obtained as cubes from aqueous solution.

Parallel cubes were obtained with KBr, RbBr, and with AmBr, even in absence of urea, whilst AmCl gave irregular growths; parallel deposits of a semi-zonal character were obtained with KI and AmI, but irregular rods were deposited from solutions of CsCl, CsBr, and CsI. Nothing could be made out with regard to NaCl, KCl, and RbCl, owing to the streaming set up. Copious precipitation immediately occurred on contact with solutions of KCN and RbCN, and of these it can only be said with certainty that the former salt was parallel.

Rubidium Cyanide.—Obtained as cubes from aqueous solution.

KCl, KBr, KI, RbCl, RbI, and AmI gave parallel cubes, the deposition as a rule being copious; RbBr gave a zonal growth, but, on heating, parallel cubes. The deposition was so rapid with NaCl, AmCl, AmBr, CsCl, and CsBr that its nature could not be made out; CsI gave irregular rods, and, finally, streaming occurred with KCN.

Ammonium Chloride.—Cubes were obtained from an aqueous solution containing urea.

The following salts gave irregular deposits of cubes: NaCl, KCl, KBr, KI, KCN, RbCl, RbBr, RbI, AmI, and (probably) RbCN; whilst parallel deposits of cubes ensued with AmBr (with or without urea), CsCl, and CsBr. CsI, on the other hand, gave irregularly orientated rods.

Ammonium Bromide.—Cubes were obtained from an aqueous solution containing great excess of urea.

Floral cubes in irregular positions were obtained from solutions of KBr, KI, KCN, RbCl, RbBr, RbI, RbCN, and AmI; whilst NaCl, KCl, and AmCl yielded parallel cubes. Parallel depositions, taking the form of 4-petal groups, were derived from CsCl and CsBr; a very finely divided

deposit was afforded by CsI, the character of which could not be made out.

Ammonium Iodide.—Obtained as cubes from aqueous solution.

CsCl, CsBr, and AmBr gave rods; NaCl and AmCl (with urea), cubes; CsI, petals—all irregularly orientated. KCN gave a very thick deposit, which was finally made out to consist of parallel cubes. The precipitation of the other salts—KCl, KBr, KI, RbCl, RbBr, RbI, and RbCN—was too dense for the determination of the nature of the growth.

V. Behaviour of solutions of sodium bromide and iodide.

Sodium bromide is deposited from its aqueous solution on rock-salt in the monoclinic form—$NaBr.2H_2O$—in irregular position, but, on heating, anhydrous parallel cubes come out. Parallel deposits of isotropic cubes (presumably anhydrous) are also immediately formed even in the cold on crystals of KCl, RbCl, KI, and RbI; and a very copious precipitate obtains with AmI and AmCl (parallel?), whilst with KBr, RbBr, and AmBr no cubic crystals seem to come out (it is of course possible that a zonal growth is partly formed, though not to be expected); but on allowing to stand in a desiccator, birefringent crystals (hydrated) are deposited. If, however, the temperature is above 50° C. parallel growths of isotropic cubes are obtained. The character of the growths on KCN and RbCN could not be made out, a thick deposit being immediately formed.

It will be observed from the above that isotropic cubes only appear immediately, where there are four variables or ions: e.g., NaBr on KCl; whilst no cubes—but in time hydrated salts—appear, where three variables are present: e.g., NaBr on NaCl. The same inexplicable behaviour is met with on turning to sodium iodide: here, parallel growths of isotropic cubes are immediately obtained on crystals of KBr, RbBr, KCl, and KCN; the deposition is too rapid with RbCl, but with AmCl and AmBr the cubes deposited are irregular. No cubic crystals have been observed to appear on crystals of NaCl, KI, RbI, and AmI—where there are only three variables; but, on heating, isotropic cubes, apparently parallel, are obtained on KI, RbI, and AmI. The nature of the growth of NaI on RbCN could not be made out.

Theoretical.

I. Discussion of the inter-relationships of the salts.

Although all the seventeen salts used in the above experiments crystallize in the same system and are of analogous chemical composition,

there is, nevertheless, considerable doubt whether they can be regarded as isomorphous in the strictest sense of the term. At the outset, sodium salts are rarely, if ever, isomorphous with the corresponding potassium, rubidium, and caesium salts, except in very complex molecules, where it is also generally found that substitution even by hydrogen does not alter the crystalline form; moreover, much evidence has been accumulated by different observers indicating that it is not permissible to regard the remaining salts as constituting a single isostructural group: upon this point, all authors are in agreement. But, how the group is to be subdivided, and what are the relationships of these sub-groups to each other, are questions difficult to decide and conducive to much controversy. It would be superfluous to give an historical summary of the views hitherto held. The following are the author's views: and it is only just to say that they are almost wholly based on the work and opinions of others.

The group must be divided into two sub-groups, which are hereafter called *A* and *B* respectively: the members of each sub-group are at least isostructural and possibly isomorphous in the strictest sense. Groups *A* and *B*, on the other hand, are not isostructural with each other; but a salt belonging to group *A* may mix with a salt of group *B* in restricted proportions, each salt taking up a little of the other, the salt taken up assuming the (labile) structure of the other: in other words the two sub-groups are isodimorphous. The classification is as follows:—

Group *A*.—NaCl, NaBr, NaI, KCl, KBr, KI, KCN, RbCl, RbBr, RbI, RbCN, AmI (and probably NaCN).

Group *B*.—AmCl, AmBr, CsCl, CsBr, CsI (and probably CsCN).

The following are the reasons for this classification:—

1. *Considerations of Molecular Volume.*

It has been shown by Tutton, as also by Muthmann and others, that the replacement of an atom of potassium by one of rubidium, or the latter by one of caesium, is accompanied by a fairly regular increase in molecular volume: this holds for all the salts investigated by Tutton (with the exception of ammonium selenate), namely, the simple and double sulphates and selenates, also for the permanganates (Muthmann) and the perchlorates; moreover, the molecular volumes of the ammonium salts approximate very closely to those of the rubidium salts—sometimes they are a little greater, sometimes a little less.

Now in the above cubic group of salts, the increase in molecular

volume in passing from a potassium to the corresponding rubidium salt regularly amounts to about 5–6 units; but on turning from a rubidium to a caesium salt one actually finds a decrease in molecular volume. Again the molecular volumes of ammonium chloride and bromide are abnormally low—even less than those of potassium chloride and bromide, whilst ammonium iodide has a normal value, being nearly equal to that of rubidium iodide.

The above irregularities disappear if the group is split up into two parts—groups *A* and *B*—the members of group *A* having relatively greater molecular volumes.

Division into groups A and B.

Group *A*.—NaCl, 26·92	(NaCN, ?)	NaBr, 32·21	NaI, 41·06
KCl, 37·49	KCN, 41·31	KBr, 43·30	KI, 53·06
RbCl, 43·10	RbCN, 48·60	RbBr, 49·30	RbI, 59·62
Group *B*.—AmCl, 34·96	(AmCN, ?)	AmBr, 43·45	AmI, 58·14
CsCl, 42·15	(CsCN, ?)	CsBr, 47·81	CsI, 57·25

A glance at the above table is sufficient to show that each sub-group exhibits regularities in molecular volumes comparable with those met with in the groups investigated by Tutton.

The sodium salts are placed in group *A* because they possess lower molecular volumes than the potassium salts; this would be expected from the position of sodium in the periodic classification, provided all the salts belong to the same isostructural group.[1]

That the sodium salts all belong to one group, in contradistinction to the ammonium salts, is conclusively proved by the absence of any sudden jump in passing from one to another.

The cyanides of potassium and rubidium are placed in group *A*, though it might seem arbitrarily. Considerable difficulties have been met with in the investigation of caesium cyanide, and this is unfortunate, for a

[1] It is worthy of note that the difference in molecular volume of the sodium and potassium salts is about twice the corresponding difference between the potassium and rubidium salts, and it may possibly be argued from this that the sodium salts ought to form a further sub-section of group *A*; still another argument in favour of this is found in the total non-miscibility of sodium chloride and potassium chloride (Krickmeyer, loc cit.). On the other hand, since the molecular volumes of the sodium salts are so low, it might be inferred that they ought to belong to group *B*; but, as will be seen later, the good cubic cleavage and, more especially, the experiments on parallel growth effectually negative this alternative.

knowledge of the molecular volume of caesium cyanide—if it proved to be lower than that of rubidium cyanide—would furnish fairly conclusive evidence for placing rubidium and potassium cyanides in group *A*, and caesium cyanide itself in group *B*. But, as will be seen later, the results of the experiments on parallel growths furnish evidence of a trustworthy character for the correctness of the above position. The elusive nature of ammonium cyanide prevented its employment in this research. It is a remarkable fact that the volume occupied by the cyanogen radical—consisting of two atoms—is about equal to the volume occupied by an atom of bromine, but less than that of an atom of iodine. This is a similar result to that derived by Tutton with respect to the volume of the ammonium radical—consisting of five atoms—compared with the volumes of the metallic atoms, rubidium and caesium. One of the contributory causes is, of course, the low molecular weight of these two radicals.

2. *Considerations of Form and Cleavage.*

The characteristic crystalline form of the members of group *A* is without exception the simple cube (sometimes octahedral facets are present); moreover, there is a perfect cubic cleavage with all the members. The cube, however, is quite a subordinate form with salts in group *B*: ammonium chloride and bromide crystallize in feathery groups which are probably combinations of {211} and {110}; caesium chloride, generally in the same form, but also in dodecahedra and cubes; caesium bromide, in dodecahedra which are as a rule elongated along a trigonal axis (Sprockhoff); and caesium iodide, in dodecahedra.

As mentioned above, ammonium chloride and bromide can be obtained in large cubes by the addition of urea to the solution, but the cubic cleavage is very imperfectly developed. The caesium haloid salts nevertheless, according to Sprockhoff, exhibit a good cubic cleavage.

3. *Considerations of Miscibility.*

The evidence derived from the degree of miscibility of pairs of salts is generally in favour of the above classification: the members of group *A* mix better with each other than do those of *A* with those of *B*. The miscibility of members of group *B* with each other has, unfortunately, not been investigated.

Below is given a list of those miscibilities which have been hitherto determined:—

(i) Members of group *A* with each other.

AmI and KI in all proportions (Gossner)[1].
KCl and KBr almost totally miscible (Fock)[2].
KI takes up 30 per cent. KBr (Fock). [(Gossner).
KCl with KI, there is a gap, not determined quantitatively

(ii) Members of group *A* with group *B*.

18 per cent. AmCl—3 per cent. KCl (Fock).
40 „ „ AmBr—1½ „ „ KBr (Fock).
AmCl with AmI, large gap (Gossner).
NaCl and AmCl do not mix at all (Krickmeyer).

Perhaps the force of this evidence is weakened by the fact that sodium chloride and potassium chloride do not mix at all, although they both belong to group *A* (see footnote on p. 245).

4. *Considerations of Parallel Growth.*

The results of the experiments on parallel growth decidedly point to the above classification: as a rule, members of group *A* form parallel growths on each other, and the same holds for members of group *B* *inter se*; while members of group *A* on group *B* (or group *B* on group *A*) almost always yield growths which are irregular.

It must be stated that the evidence derived from etching is not in agreement with the above classification: thus, AmCl (Tschermak); KCl (Brauns); KBr, RbCl, RbBr, and CsBr (Sprockhoff) all belong to the tesseral-holoaxial or gyrohedric-hemihedral class of the cubic system. But KI, CsCl, and CsI (Sprockhoff) as well as NaCl (Brauns) belong to the holohedral class.[3] It will thus be seen that a classification based on symmetry, as derived by etching, only succeeds in separating salts which otherwise resemble each other, just as well as it brings together salts which have the least analogies of all.

The author believes that the above considerations are strongly in favour of the classification here adopted. Whether each sub-group is further divisible or no can only be decided when evidence, much more

[1] Zeits. Kryst. Min., 1905, vol. xl, p. 69.

[2] Zeits. Kryst. Min., 1897, vol. xxviii, p. 351.

[3] The symmetry of a crystal, as derived from etching figures, does not necessarily give the real symmetry; for the latter, although it cannot be higher, may nevertheless be lower than the former. Hence, it is not absolutely excluded that the real symmetry of the above compounds is the same, and possibly even lower than the symmetry exemplified by the tesseral-holoaxial class.

than is at present available, has been accumulated. The experiments on parallel growth do not furnish any evidence, for or against, in this direction.

It is interesting to note that direct evidence for the isodimorphism of ammonium chloride has been produced by Lehmann[1], who observed that feathery cubes separate from hot solutions which, on contact with the ordinary rod-modification, were transformed into the latter. Again, from an aqueous solution containing a little cadmium chloride, rounded cubes were obtained which on standing 'explode' into skeletal crystals.

More reliable evidence would be obtainable from a careful determination of the specific gravities of the isomorphous mixtures given by ammonium and potassium bromides, for if the specific gravity of the labile modification of ammonium bromide, taken up by the potassium bromide, were found different from (and probably less than) the specific gravity of the ordinary modification, we should have direct and conclusive evidence of isodimorphism.

II. Connexion between Parallel Growth and Molecular Volume.

The results of the experiments on parallel growths are collected in the accompanying table in which the members of group *A* are followed by those of group *B*; the salts in each group are arranged in order of molecular volume. The table is divided up by means of heavy lines into four areas corresponding to the growths of the following salts:—(1) *A* on *A*, (2) *B* on *A*, (3) *A* on *B*, and (4) *B* on *B*.

The method of construction of the table is best illustrated by taking an example. In the vertical column headed by KBr and horizontally opposite to RbCN there is a letter P; this denotes that the growth of crystals (deposited from a solution) of KBr on a crystal of RbCN is parallel; similarly, under the column headed RbCN and horizontally opposite to KBr the letter P again denotes that the growth of crystals (deposited from a solution) of RbCN on a crystal of KBr is parallel. Ir denotes that a growth was irregular (not parallel), and Z that a (parallel) zonal growth is obtained. For the signification of the letters placed in brackets see below, under 'Members of group *A* on each other'. From the method of construction of this table, it is obvious that, the less the difference between the molecular volumes of two

[1] Zeits. Kryst. Min., 1885, vol. x, p. 321.

salts, the closer will the squares, which represent the growths in the table, approximate to the diagonal line drawn from the top left hand to the bottom right hand corner.

RESULTS OF EXPERIMENTS ON PARALLEL GROWTH.

Members of Group *A* on each other. Group *B* on Group *A*.

Vol.	26·92	32·21	37·49	41·06	41·31	43·10	43·30	48·60	49·30	53·06	58·14	59·62	34·96	42·15	43·45	47·81	57·25
	NaCl	NaBr	KCl	NaI	KCN	RbCl	KBr	RbCN	RbBr	KI	AmI	RbI	AmCl	CsCl	AmBr	CsBr	CsI
Cl		P	P	P?	P	P	P	P	Ir	P	Ir	Ir	Ir	Ir	Ir	Ir	Ir
Br	(P)		(P)	P	?	P	(P)	?	P	P	?	P	?	P?	?	?	Ir
I	P	P		P	P	P	P	P	P	Ir	Ir	Ir	Ir	Ir	P	Ir	Ir
I	(P)	(P)	(P)		(P)	(P)	(P)	?	(P)	(P)	(P)	?	?	?	?	?	?
CN	(P)	?	P	P		Z	Z	P	?	P	P	(P)	?	?	?	?	Ir
Cl	P	P	(P)	P?	Z		Z	P	(P)	(P)	Ir	Ir	Ir	Ir	Ir	Ir	Ir
r	P	P	P	P	Z	Z		P	P	P	P	P	P	P	P	Ir	Ir
CN	(P)	?	P	?	(P)	P	P		Z	P	P	P	?	?	?	?	Ir
Br	Ir	P	P	P	?	P	P	Z		P	P	P	Ir	Ir	Ir	Ir	Ir
	P	P	Ir	P	P	P	P	P	P		Z	P	P	Ir	P	Ir	Ir
I	Ir	?	(Ir)	P	P	(Ir)	(P)	(P)	(P)	(Z)		Z	Ir	Ir	Ir	Ir	Ir
	Ir	P	Ir	?	P	Ir	P	(P)	P	Z?	Z		Ir	Ir	P	Ir	Ir
Cl	Ir	?	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir		P	P	P	Ir
I	?	?	?	?	?	?	?	?	?	?	?	?	(P)		(P)	?	?
Br	P	P	P	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	P	P		P	?

Group *A* on Group *B*. Group *B* on each other.

(P = parallel growth; Ir = irregular (non-parallel) growth; Z = zonal growth.)

The discussion may be conveniently divided into three parts corresponding respectively to growths where

(1) both salts belong to group *A*,

(2) both salts belong to group *B*, and

(3) one salt belongs to *A* and the other to *B*.

1. *Members of group A on each other.*

It is obvious that with each pair of substances we have two cases, namely, salt (1) on salt (2), and salt (2) on salt (1); and whenever it was possible to come to a definite conclusion, it was always found that the growths were either both parallel or both irregular: e.g., both KCl on NaCl, and NaCl on KCl gave parallel growths, but RbBr on NaCl and NaCl on RbBr both afforded irregular deposits. This is, of course, what one would expect.

Now, as mentioned above, with certain pairs of salts it was only possible to determine the character of the growth in one direction: e.g., RbCl on RbBr was made out to be parallel, but the deposition of RbBr on RbCl was too rapid to enable one to decide whether it was parallel or no. The fact that a parallel growth is obtained one way is strong evidence for believing that the same is really obtained the other way, and, in order to make the table as complete as possible, the letter P is placed in brackets; the same remarks hold for (Ir). Finally, in a few instances, the nature of the parallel growth could not be determined either way, and notes of interrogation are then placed in the table.

This isostructural group is big enough, and only just big enough, to show that parallel growths are conditioned by a similarity of molecular volume, or perhaps it were better to say that irregular growths are only met with where the molecular volumes differ considerably.

It is seen from the table that the irregular growths are all grouped in the top right hand and the bottom left hand parts of the diagram, and the line of demarcation is essentially, though not perfectly, indicated by the double line: the parts thereby cut off are chiefly occupied by irregular growths and the rest of the field is wholly taken up with the parallel growths.

The parallel growths met with in the two 'irregular regions' are those in which the salts NaBr and NaI are concerned, and it was pointed out in the experimental part of this memoir that the behaviour of these salts is in many other respects of an equally inexplicable character, so that a further investigation is desirable. For a discussion of zonal growths see p. 252.

2. *Members of group B on each other.*

Owing to the difficulties encountered in obtaining crystals of a sufficient size of the salts CsCl, CsBr, and CsI, we are here restricted to the

growths on cubes of AmCl and AmBr crystallized from solutions containing urea. But the results, as far as they admit of interpretation, point in no less degree to the importance of similarity of molecular volume in conditioning a parallel growth; this is immediately seen from the fact that, of the four salts AmBr, CsCl, CsBr, and CsI, the last is the only one to give irregular growths on crystals of AmCl. Unfortunately, the character of the growth of CsI on AmBr could not be definitely determined owing to the fineness of the deposit: the latter may be possibly consequent on the formation of a parallel growth, but this, of course, is by no means necessary.

3. *Members of group A on those of group B, and vice versa.*

It will be seen from the table that as a rule the growths are here irregular, which is an indication that these pairs of salts are not isostructural. But in some nine cases (possibly ten) parallel growths are obtained and they are tabulated below:—

KCl, 37·49 / AmBr, 43·45	CsCl, 42·15 / KBr, 43·30	CsCl, 42·15 / NaBr, 32·21 ?	NaBr, 32·21 / AmBr, 43·45
KBr, 43·30 / AmCl, 34·96	KI, 53·06 / AmBr, 43·45	RbI, 59·62 / AmBr, 43·45	NaCl, 26·92 / AmBr, 43·45
	KBr, 43·30 / AmBr, 43·45	KI, 53·06 / AmCl, 34·96	

With the first pair, parallel growths of a semi-zonal character are obtained, no matter which salt is the solute; the next three pairs could only be investigated in one direction: the second and third with the salt of group *B*, the fourth with the salt of group *A*, as solute. But the remaining six pairs only yielded parallel growths when the salt of group *A* was used as the crystal, the salt of group *B* being the solute; if crystals of group *B* were taken, and solutes of group *A*, then the growths obtained were irregular. This can hardly be caused by the roughness of the surface (owing to the imperfect cleavage) in the salts of group *B*, for, as mentioned above, KCl does give a parallel growth on AmBr.

It will be noted that the difference between the molecular volumes in certain of these pairs is considerable, while many other pairs, which fail to give parallel growths, exhibit far closer molecular volumes. Is it possible that the cubes of AmCl and AmBr, deposited in parallel position on the salts of group *A*, are crystals of the labile (group *A*) forms of AmCl and AmBr?; for the molecular volumes of labile AmCl

and AmBr would be about 42 and 48 respectively, and the differences between these numbers and the molecular volumes of the salts on which they were deposited would be very small, and therefore parallel growths would be expected (the crystals being isostructural). On the other hand, a crystal of AmCl or AmBr may not be able to force a salt of group *A* to take up the labile (group *B*) form; and hence parallel growths may not be formed. This is a hypothesis which can be proved or disproved by a study of parallel growths of isodimorphous pairs of substances, which crystallize in two different systems: and the author hopes to attack this problem in the near future.

4. *Zonal Growths.*

With some of the pairs of substances investigated, separate discernible crystals of the solute are not formed on the mother-crystal, but, as the solution evaporates away, the solute is evenly deposited on the whole of the surface; a zonal growth (Schichtkrystall) is thereby formed. Under a high magnification, a fine network of lines is often visible parallel to the cube-edges. It was previously shown by the author (loc. cit.) that this behaviour is characteristic of isostructural substances, the molecular volumes of which are practically identical; and it is satisfactory to note that the present work is in complete accord with that generalization.

It is seen from the table that the zonal growths lie close to the long diagonal running from the top left hand to the bottom right hand corner, which is the line expressing equality of molecular volume.

Now, as pointed out on p. 243, no separate crystals appear when, say, a drop of a solution of NaBr is placed on a crystal of RbBr, and yet the molecular volumes of these salts are greatly different. But on forcing the crystallization by heating, a most beautiful and copious formation of parallel cubes obtains. On the other hand, with the true zonal growths very few, if any, separate cubes (in parallel position) appear: the solute is deposited, partly in an even manner on the whole of the surface, and partly in ridges which often have crystallographic outlines parallel to those of the mother-crystal. This behaviour was especially observed with the alums, which possess almost identical molecular volumes, and with solutions of ammonium or thallium perchlorate on crystals of rubidium perchlorate. When a crystal of potash-alum and a solution of ammonia-alum are employed, a ridge, hexagonal or triangular in outline, is gradually formed round the edges of the upper surface of the crystal, and many drops of solution may be successively

added and evaporated away by heat, without the separation of separate octahedra. Again, with rubidium perchlorate, the polarization-tint gradually alters owing to the thickening of the crystal by the even deposition of a layer of thallium or ammonium perchlorate.

III. Interpretation of Parallel Growths in terms of Topic Axes.

The simplest assumption one can make with regard to parallel growths is that they are brought about by a fitting together of similar structures. And it has been shown that in the above two isostructural sub-groups, as well as in the two isostructural groups previously studied by the author (the calcite-sodium-nitrate and the barytes-perchlorate groups), parallel growths are conditioned by similarity of molecular volume. Now, by combining the molecular volume with the axial ratios in a simple way, the distances between adjacent particles of the crystal structure may be calculated; these distances are known as topic axes. Hence, if parallel growths result from the close fitting of two similar structures, it would follow that the topic axes of those pairs of substances which yield such growths should be very close. This was found to be the case with the groups previously studied, and the present investigation affords additional confirmation.

With the salts of group *A*, the similarity of cleavage speaks for a similarity of structure. If, therefore, cleavage cubes of the members of the group be taken of such sizes that their volumes are proportional to the molecular volumes of the substances, their edges may be taken to represent the intervals between the crystal-units spaced along those directions, and are, in fact, the topic axes.

The latter are calculated from the formulae, $\chi = \psi = \omega = \sqrt[3]{V}$, where V = the molecular volume.

Topic Axes of salts of group A.

NaCl, 1·3911	NaBr, 1·4768	KCl, 1·5534	NaI, 1·6013
KCN, 1·6045	RbCl, 1·6274	KBr, 1·6299	RbCN, 1·6939
RbBr, 1·7020	KI, 1·7741	AmI, 1·7981	RbI, 1·8132

Similarly, the different compounds in group *B* can be compared with each other with regard to topic axes, but the topic axes of group *B* cannot be compared with those of group *A*.

Topic Axes of salts of group B.

AmCl, 1·5177	CsCl, 1·6154	AmBr, 1·6318
CsBr, 1·6846	CsI, 1·7889	

Now, a comparison of the collected results, given in the large table on p. 249, with the above topic axes, will show that, within each isostructural group, irregular growths are only afforded by those pairs of salts the topic axes of which betray considerable differences. In other words, a fitting of the one structure into the other cannot take place when the distances apart of the crystal-units, as given by topic axes, differ greatly.

Addendum.—An important contribution to the theory of crystal-structure has recently been made by Barlow and Pope (Journ. Chem. Soc. Trans., 1906, vol. lxxxix, p. 1675), which seems to point to the possibility of correlating dissimilar structures. In this memoir the authors advance the idea that a crystalline medium results from the close-packing of identical groups of spheres; each group represents a chemical molecule, and is made up of as many spheres as there are atoms in the molecule; further, the volume of each sphere is approximately proportional to the valency of the atom it represents. It must be noted that the absolute volume of an atom of any given element is not necessarily the same in different compounds of that element, but that a dilatation may occur in passing from one compound to another. The sum of the valencies of the constituent atoms is known as the valency volume.

Now, topic axes result from the combination of axial ratios with molecular volumes; if, however, valency volumes are substituted for molecular volumes, a new set of constants, which Barlow and Pope term equivalence parameters, are obtained.

From the above conceptions and by the use of the equivalence parameters, the authors have been able to explain why certain regularities—hitherto unexplained—subsist between the members of a morphotropic group such as that of the humite minerals; and what is even more important, from a consideration of valency volume, they have constructed assemblages of spheres, derived from each other in a simple way, which account for the crystalline form of many aromatic derivatives.

But in their memoir the authors certainly seem to suggest that equivalence parameters possess some advantages over topic axes—even within an isomorphous or, more generally, an isostructural series—and can be employed in place of them.

The writer would remark on this that although valency volumes may be invaluable for certain purposes, yet topic axes are not the less important when comparisons have to be made among the members of an isostructural group. For, although the crystalline structure may be

deducible from the chemical constitution by means of valency volumes, yet it is only by means of molecular volumes, and therefore of topic axes, that one can compare the relative dilatation of the valency volumes when they unite to form different structures. It is obvious, then, that equivalence parameters do not give the relative magnitudes of the crystal-units of two isostructural substances unless they be further combined with the molecular volumes. Now, since the valency volumes of members of an isostructural group are generally identical, the valency volume may be neglected for purposes of comparison within such a group, and the magnitudes of the crystal-units on Barlow and Pope's theory, or the relative distances between adjacent particles (supposed infinitely small) on the generally received theory, are in reality simply given by the topic axes.

That the consideration of topic axes is indispensable, at any rate within an isostructural group, is proved by the writer's investigations, all of which lead to the conclusion that the possibility of parallel growths can be predicted from a comparison of the topic axes; on the other hand, the following table (p. 256) serves to show that such predictions could not be made from equivalence parameters. The table refers to the isostructural barytes-perchlorate-permanganate group, previously studied by the writer (loc. cit.). Of all the nine soluble salts enumerated, only potassium perchlorate and permanganate form parallel growths on the barytes minerals.

It is seen from the table that, with the exception of the ammonium salts, the equivalence parameters do not show great differences; nor can they be arranged in order of magnitude, for it will be seen that some salts possess a very close x-value to those of the minerals, while others exhibit almost identical y-values. And it would be impossible to foretell from the table which salts should yield parallel growths. A perusal of the topic axes, however (loc. cit.), will show that there is a remarkable relation between similarity of topic axes and formation of parallel growths.

The valency volumes of the halogen salts all possess the same value (namely, 2), with the exception of the ammonium salts, which, together with the cyanides, have the value 8. In the cubic system the equivalence parameters are given by the cube roots of the valency volumes: the equivalence parameters, then, have the values $\sqrt[3]{2}$ or $\sqrt[3]{8} = 1{\cdot}2599$ and 2 respectively, and a consideration of equivalence parameters would lead to erroneous expectations with regard to the formation of parallel growths.

Equivalence Parameters of the Barytes-Perchlorate-Permanganate Group.

	Val. vol.[1]	x	y	z
Celestine ...	12	2·2457	2·9180	3·6624
Anglesite ...	12	2·2485	2·8636	3·6924
Barytes ...	12	2·2394	2·9381	3·6478
$KClO_4$ ...	10	2·1176	2·7138	3·4749
$KMnO_4$ ...	10	2·1394	2·6835	3·4836
$AmClO_4$ ...	16	2·5050	3·1581	4·0449
$RbClO_4$ ...	10	2·1439	2·6913	3·4662
$AmMnO_4$ ...	16	2·5301	3·0992	4·0810
$TlClO_4$ ...	10	2·1677	2·7171	3·3958
$RbMnO_4$ ...	10	2·1806	2·6238	3·4957
$CsClO_4$ ...	10	2·1776	2·6644	3·4574
$CsMnO_4$ ...	10	2·2242	2·5615	3·5105

Conclusions.

The above work, taken in conjunction with the author's previous investigations, proves that in an isostructural group of substances, irregular growths are only obtained where the molecular volumes differ considerably; and this holds good no matter whether the group consists partly of insoluble minerals and partly of soluble salts, or wholly of soluble salts. But the present memoir especially emphasizes that these conclusions only hold for isostructural substances, and a study of parallel growths will therefore serve to discover whether all the members of a given group are really isostructural.

The investigation of the groups already made does not enable one to predict whether the members of any other isostructural group will all yield parallel growths, because for each group there is a 'crucial difference of molecular volume', which will vary with the group taken; but, when this crucial difference has been determined by a limited number

[1] The values of the valency volumes were derived from the following considerations. Barlow and Pope take S and O as divalent; N, trivalent; and H, Cl, K, Rb, Cs, and Tl monovalent. The writer considers that Ba, Pb, and Sr must be divalent, and has deduced the valency volumes of the permanganates and perchlorates from that of the sulphates by Barlow and Pope's second principle: the replacement of Ba by K necessarily requires a decrease by one in the valency volume of the remaining complex. The valency volume of $KMnO_4$ is therefore 10, and this agrees with the valency volume of $KClO_4$ which must necessarily be 10 since Cl is monovalent. If manganese be taken as divalent ($KMnO_4 = 11$), results are obtained in the equivalence parameters which are at a still greater variance than in the given table.

of observations, it can confidently be expected that pairs of substances exhibiting a less difference of molecular volume will afford parallel growths.

It is obvious from the present investigation that the crucial difference of molecular volume is a very great one, so that it will not be surprising if no other isostructural group of soluble salts can be found of such a size as to render possible the attainment of *irregular* growths.

The author is greatly indebted to the Chemical Society for defraying the expenses of this research by means of a grant. It is again his pleasant duty to thank Professor H. A. Miers for the valuable advice received during the progress of the research.

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Ilmenite from Jacupiranga, Brazil.

By G. F. Herbert Smith, M.A., D.Sc., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read November 13, 1906.]

DURING the summer of this year certain crystals of zirkelite from Ceylon were entrusted to the author for crystallographical investigation, and in that connexion the specimens placed under this species in the British Museum collection were examined for the sake of comparison. The whole of the latter specimens come from Jacupiranga in São Paulo, Brazil: some of them had been presented by Dr. E. Hussak and formed part of the material on which he and Dr. G. T. Prior[1] conducted their investigation which led to the first discovery of zirkelite, while the remainder were purchased subsequently. The latter included a lot of small, brilliant crystals (numbered 86034 in the General Register) which differed so markedly in lustre from the other crystals as to suggest that they had been incorrectly determined. Goniometrical examination leaves no doubt that the crystals are really ilmenite, a mineral already described by Dr. Hussak[2] from the same locality. His crystals have three habits, viz., *cr*, *crn*, and *crsn*.[3]

The crystals examined by the author have also three habits, viz., *cam*, *camrX* (fig. 1), and *cnX* with *r* and *s* small (fig. 2), slightly different

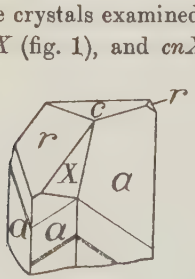


Fig. 1.

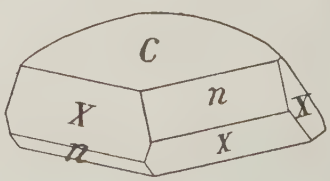


Fig. 2.

Ilmenite from Brazil.

[1] Min. Mag., 1895, vol. xi, pp. 86–88.

[2] Min. Petr. Mitt. (Tschermak), 1895, vol. xiv, p. 407.

[3] The notation adopted in Dana's 'System of Mineralogy,' sixth edition, 1892; and used also by Dr. Hussak.

from the above. The form $X = (53\bar{1}) = (44\bar{8}3)$ had not been definitely noted on ilmenite until it was found by Mr. R. H. Solly[1] on crystals collected by him in the Binnenthal, Switzerland: on these crystals the form is represented by very small faces, whereas on those from Brazil it is most prominent, particularly in the case of crystals such as that shown in fig. 2. It must, however, not be overlooked that Dr. Hussak[2] described prismatic crystals in which the prism-faces are strongly striated in the horizontal direction and which are terminated by a relatively small basal plane and by a pyramid-form steeply inclined to it. This form is no doubt X, although, as he points out, since there is no form present to determine definitely the orientation, it might possibly be $\frac{1}{2} = (4\bar{1}\bar{1}) = (50\bar{5}2)$. Further, these crystals give a relatively strong reaction for magnesia, and in minute splinters transmit light of a violet colour.

The present crystals were found by Dr. Prior, using a microchemical test (the precipitation of ammonium-magnesium phosphate), to contain some, but probably only a very small percentage of magnesia. On the other hand, they are opaque, even in the thinnest fragments, and the prism-faces are striated obliquely (cf. fig. 1). The faces of the form a are, indeed, frequently striated parallel to their intersection with the contiguous faces of the form r, and thus reveal the hemihedral type of symmetry characteristic of this mineral; occasionally each face of the form X is also striated parallel to its intersections with the nearest face of the form r.

The measurements made on eight crystals are summarized in the following table:—

Measurements from $c = (111) = (0001)$.

Form.	Calculated[3] Values.	Observed Means.	No.	Limits of Observations.
$r = (100) = (10\bar{1}1)$	57° 58½′	57° 58½′	12	57° 49′ – 58° 6′
$X = (513) = (44\bar{8}3)$	74 50½	74 49	18	74 25 – 75 8
$a = (31\bar{1}) = (22\bar{4}3)$	61 33	61 33	5	61 16 – 61 45
$e = (11\bar{1}) = (02\bar{2}1)$	72 38	72 21	2	72 14, 72 28

[1] Min. Mag., 1906, vol. xiv, pp. 184–186.

[2] Loc. cit., p. 408.

[3] Calculated from the element of N. I. Koksharov, 'Materialien zur Mineralogie Russlands,' 1870, vol. vi, p. 357, which is adopted by Dana, 'System of Mineralogy,' sixth edition, 1892, p. 217.

The azimuthal readings closely approximated to 30° or 60°. The differences from these values rarely exceeded 2′ in the case of well-defined reflections; 10′ was the maximum noted even in the case of a confused blur. The observed values for *ca* and *cm* approached 90° closely.

The forms *crX* and *n*, and, where present, *a* and *m*, are well developed. The form *s* was only twice observed and in each case the face was minute.

Note on the thirty-two classes of symmetry.

By Harold Hilton, M.A.
Fellow of Magdalen College, Oxford.

[Communicated by Professor Miers, and read November 13, 1906.]

CONSIDERABLE confusion exists with regard to the nomenclature of the thirty-two possible classes of symmetry and their classification into systems. Each class is usually denoted by a name and a symbol; but as every author invents his own names and symbols (the latter being often merely arbitrary numbers) the whole nomenclature is hopelessly confused. This is due to the fact that a different classification into systems, and consequently a different nomenclature is suggested according as the subject is approached (1) from the geometrical aspect based on the law of rational indices alone, (2) from the aspect of the structure-theory, (3) from the aspect of the practical crystallographer. Thus, for example, Dr. A. Schoenflies [1] finds two distinct classifications necessary according as the subject is approached from aspect (1) or (2).

The question arises whether a simple nomenclature and classification are possible, which will reconcile the differences between the practical and theoretical crystallographer. It is usual to take as fundamental symmetry-elements n-al axes of the first and second sort; where by the former is meant a rotation-axis l such that the crystal is brought to self-coincidence by a rotation through $2\pi \div n$ about l (but through no smaller angle), and by the latter is meant an axis l of rotatory-reflexion (Drehspiegelung) such that the crystal is brought to self-coincidence by a rotation through $2\pi \div n$ about l followed by a reflexion in a plane perpendicular to l. Now we can avoid many difficulties if we define an n-al symmetry-axis of the second sort as an axis l of rotatory-inversion (Drehinversion [2]) such that the crystal is brought to self-coincidence by a rotation through $2\pi \div n$ about l followed by inversion about a point on l. Then any line through a centre of symmetry is a 1-al axis of the

[1] 'Krystallsysteme und Krystallstructur,' 1891, pp. 146 and 148.

[2] As is done by T. Liebisch in his 'Grundriss der physikalischen Krystallographie' (1896), though he does not point out the logical conclusion of his method.

second sort and a line perpendicular to a symmetry-plane is a 2-al axis of the second sort. An n-al axis of the second sort is equivalent to an n-al rotation-axis plus a centre of symmetry if n is odd, and to an $\frac{1}{2}n$-al rotation-axis plus a perpendicular symmetry-plane if n is even and $\frac{1}{2}n$ odd.

The thirty-two classes will then be grouped naturally into seven systems containing the classes with (1) only 1-al axes (of either sort), (2) one 2-al axis, (3) three perpendicular 2-al axes, (4) a 3-al axis, (5) a 4-al axis, (6) a 6-al axis, (7) more than one n-al axis ($n>2$). These systems coincide exactly with the triclinic, monoclinic, orthorhombic, rhombohedral, tetragonal, hexagonal, and regular systems of the structure-theory and practical crystallography.

As an instance of the simplicity gained by the proposed definition we notice that the same proof of the fact that every n-al symmetry-axis is parallel to a possible edge applies to axes both of the first and second sort ($n=3$ being an exception in both cases).

The classes with a single n-al axis of the first or second sort may be denoted by the symbols C_n and c_n respectively; those with a single n-al axis of the first or second sort and a perpendicular 2-al rotation-axis by D_n and d_n respectively (it is convenient, however, to write C for C_1, D for D_2); and those with an n-al axis of the first sort and a perpendicular 2-al axis of the second sort by δ_n. The tetrahedral and octahedral classes may be denoted by T and O. The addition of a centre of symmetry is conveniently shown by changing C, D, T, O into Γ, Δ, Θ, Ω respectively. These symbols have the advantage of being both simple and descriptive. For comparison they are tabulated below with the corresponding numbers from Professor Miers's 'Mineralogy' (1902, p. 280).

Triclinic	C, Γ	1, 2
Monoclinic	C_2, c_2, Γ_2	4, 3, 5
Orthorhombic	δ_2, D, Δ	7, 6, 8
Rhombohedral	C_3, c_3, δ_3, D_3, Δ_3	9, 15, 12, 10, 19
Tetragonal	C_4, c_4, Γ_4, δ_4, D_4, d_4, Δ_4	21, 22, 24, 25, 23, 26, 27
Hexagonal	C_6, c_6, Γ_6, δ_6, D_6, d_6, Δ_6	14, 11, 17, 18, 16, 13, 20
Regular	T, Θ, θ, O, Ω	28, 30, 31, 29, 32

If the suggestion here thrown out is adopted, all diagrams illustrating crystallographic theory should be drawn on the gnomonic projection. Diametrically opposite points on the sphere of reference are represented by the same point on the plane; the projection of any point being

marked with a × or a ○ according as the point lies on the half of the sphere nearer to or remote from the plane of projection. Thus the projections of all co-zonal poles lie on one straight line instead of on one or other of two circles as in the usual representation by the stereographic projection. The main objection to the use of the gnomonic projection (namely that the projection cannot be contained within convenient limits) does not apply to illustrative figures; for we may always choose the position of the crystal poles so that the gnomonic diagram occupies a convenient space.

University College,
Bangor, North Wales.

OBITUARIES.

Samuel Lewis Penfield (1856–1906).

(With a Portrait, Plate VI.)

In the person of Professor Penfield the Mineralogical Society has lost an eminent Honorary Member, whose death has deprived Yale University of a brilliant and inspiring teacher, and has robbed our science of one of the most ardent of modern investigators. When a man imbued with the genius and the zeal for original research passes away in the fullness of years we can at any rate feel that he has accomplished the work for which he was best fitted and has bequeathed the full results of his abilities to his successors; but when a man, like Penfield, is taken in the prime of life, while his powers are ripe for the achievement of new discoveries, and while past success is being crowned by the promise of even more mature work, the loss is irreparable.

Penfield was born on January 16, 1856, at Catskill in New York, and was the son of a prominent merchant of that town; he was educated at home and at the local school, from which he passed to the academy at Wilbraham, Massachusetts, and thence, at the age of eighteen, to the Sheffield Scientific School at Yale University. He graduated with honours in 1877, having followed the course of chemistry. He had always been attracted towards mathematics and natural science, and shortly after taking his degree found an opening which led him into the paths of mineralogical research.

Professors G. J. Brush and E. S. Dana were just beginning their investigation of the minerals from Branchville, Connecticut, and they enlisted the services of Penfield and his classmate and life-long friend, H. L. Wells, who had become assistants in the laboratory of analytical chemistry, and were ready to undertake the necessary analyses. The two young men had thus at the outset of their career the opportunity of studying many new and interesting minerals. Penfield himself was shortly afterwards transferred as assistant to the mineralogical laboratory. Among the minerals which he analysed during this period were eosphorite, triploidite, dickinsonite, fairfieldite, fillowite, triphylite, childrenite, amblygonite, cymatolite, and spodumene.

In 1880 he proceeded to Germany, and for two semesters worked with Professor Fittig in Strassburg at organic chemistry, publishing a joint

research with him on some organic compounds in 1882. Although Groth was at that time Professor of Mineralogy in Strassburg, and Penfield seems to have attended some of his lectures, his work was entirely on the organic side, and he was evidently contemplating the career of a chemist. His earlier work had, however, given him an interest and an experience in mineralogical chemistry, which were soon to find an application.

At this time the post of Instructor in Mineralogy at the Sheffield Scientific School, under Professor Brush, became vacant, and in 1881 Penfield was offered and accepted the position. During the next two years he published papers on monazite, scovillite, lithiophilite, descloizite, and beryl.

In 1884 he returned to Germany, in order to perfect himself in the methods of physical mineralogy, and studied during the summer semester with Professor Rosenbusch at Heidelberg. In 1888 he became Assistant Professor, and in 1893 full Professor of Mineralogy at the Sheffield Scientific School, and till the end of his life devoted himself with untiring zeal and energy to the twofold duties of his position—teaching and research.

Penfield's scientific publications extend over a period of very nearly thirty years, and amount to more than 110 in number. The earlier papers deal, for the most part, with the chemical composition of various minerals, but he became more and more interested in the study of their crystalline form, and towards the close of his life he devoted himself ardently to crystallographic problems and methods.

Throughout his whole career his researches were conducted with consummate skill and perseverance. Many of them led to results of the highest importance: it is only possible here to call attention to a few of the most prominent as types of his work.

One of the striking discoveries with which his name is associated is that of the isomorphous replacement of fluorine by hydroxyl. His very first published scientific paper was in 1877 on the composition of triphylite, one of the Branchville minerals. In the following year Brush and Dana, in the first of their papers upon these minerals, quoted Penfield's analysis of triploidite and pointed out that it led to the remarkable conclusion that hydroxyl can replace fluorine in a series of minerals so closely related as to be considered isomorphous. Little attention was paid to this statement at the time, except in the way of opposition: many of Penfield's subsequent analyses contributed further evidence of the same replacement, but they excited further opposition on

the part of many chemists: Rammelsberg, for example, always refused to accept Penfield's conclusions, and as late as 1895 in the second supplement of his 'Mineralchemie' criticized the view as quite untenable. But by this time the evidence accumulated by Penfield was too strong to be ignored, and to-day hydroxyl plays a well-recognized part in mineral-formulae as equivalent to fluorine.

An important application of the principle is given in the memoir upon the chemical composition and related physical properties of topaz, which he made in conjunction with J. C. Minor, and which is a model of the best type of scientific research; work which introduces method and order where previously irregularities had prevailed in what was known of a common mineral. The authors showed that the percentage of water, which is only small, and had previously been regarded as the result of incipient decomposition, increases as that of fluorine diminishes, and that different specimens of topaz, if arranged in order of their fluorine-percentage, exhibit a regular progressive change in specific gravity, in refractive indices, in birefringence, and in optic axial angle. This enabled them to refer all topaz to the exceedingly simple formula $(AlF)_2SiO_4$, in which F is replaceable by OH.

Another most remarkable investigation, in which the same replacement is again invoked, was that of the chondrodite group, whose complex crystallographic characters had been deciphered by Scacchi, vom Rath, and others. Penfield and W. T. H. Howe succeeded in proving that the group consists of three species distinct in chemical composition as well as in crystalline form, and differing progressively by a molecule of Mg_2SiO_4; also that the length of the vertical axis is proportional to the number of the magnesium atoms in the formula. This striking morphotropic relationship rendered it possible to predict, for the first time in the history of mineralogy, the composition and form of a hitherto undiscovered mineral, and constituted a very notable scientific advance.

Among the more refined and difficult of his chemical researches may be mentioned those on tourmaline, canfieldite, spangolite, connellite, hamlinite, bixbyite, parisite, and his last published (1906) memoir on stibiotantalite.

In addition to the new minerals analysed for Brush and Dana, as mentioned above, he established, in conjunction with other authors, the following new species: bixbyite, canfieldite, clinohedrite, gerhardtite, glaucochroite, graftonite, hamlinite, hancockite, leucophoenicite, nasonite, nesquehonite, pearceite, roeblingite, and spangolite.

Possessed not only of extraordinary insight and quick apprehension,

but also high inventive skill and dexterity of manipulation, Penfield could not fail to be one of the most gifted and successful of mineral chemists. He possessed the same qualities as a crystallographer, but his chief interest in crystallography was as a practical means of mineralogical research; and he devoted much time to the determination of the geometrical and physical characters, not only of minerals, but also of laboratory compounds. Among the most noteworthy of his crystallographic studies were the determination of clinohedrite, argyrodite, pearceite, sperrylite, and the double halides prepared by Wells.

In much of his work he enlisted the co-operation of his assistants and pupils.

Towards the end of his career, when his mind was much occupied with teaching, he devoted much thought to practical and graphic methods for the representation of crystals, and his protractors and the methods of drawing and projection which he described are now well known. To this period belong his papers upon the stereographic projection and its application to geographical maps and sailing charts, a subject for which he anticipated important developments in the future.

Penfield's clearness of exposition is nowhere better exhibited than in the revised and enlarged edition of G. J. Brush's 'Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis,' which was published in 1896, and was followed by several other editions. The introductory chapters which he wrote for this book are models of clear and lucid treatment, and among the very best that can be placed in the hands of elementary students.

For a few years before his death his health was such that he was obliged to husband his strength with great care, and to set very definite limits to the work that he could undertake; nothing was more characteristic of the man than the courage and determination with which he set himself to do the work of which he was still capable. The planning and equipment of his new laboratories in Kirtland Hall was at that time a great pleasure to him.

In a cheery letter written a few months before his death he wrote—'I have to be careful not to take too much exercise or exert myself physically and my hours of work are very much shortened. I ought not to get tired in any way, and I tire easily, so I have to be very careful and constantly on my guard. I go to my laboratory every day and get in about five hours' work. As I look back upon the last three years I can see that something considerable has been accomplished. My

troubles came just as my new laboratory was being started. It has taken a great amount of time and energy, but energy well spent, and the work is done. . . . It is a great delight now to work in my new building where the surroundings are most attractive and everything can be kept clean and neat.' Then after a description of the work on which he was engaged—'I have other things also on hand or in my mind, but I cannot put out work as fast as I formerly did. During hours allowed for study I prefer to work rather than read. I am not complaining; I am so much better than I ever expected to be three years ago.'

He died on August 12, 1906.

In January 1897 he had married Miss Grace Chapman of Albany, New York, who survives him.

None who knew Penfield could fail to be impressed by the earnestness, simplicity, and sincerity of his character: in scientific and intellectual matters he was inspired by a boyish enthusiasm and the keenest enjoyment of life and of the work and occupation of an active student and teacher. He endeared himself to colleagues and pupils alike, and made many warm and enduring friendships in Europe and America. Those who were privileged to enjoy his society when he visited Europe in 1894 and 1897, or to see him among his colleagues in their bachelor quarters at the Sheffield Scientific School, or later in the enjoyment of a happy married life in his own peaceful home, carried away the recollection of a sweet and affectionate nature, and feel that by his death they have lost one of the most warm-hearted and sincere of friends.

H. A. M.

Robert Philips Greg (1826–1906).

(With a Portrait, Plate VII.)

Born at Manchester on March 23, 1826, Robert Philips Greg passed away at his residence, Coles Park, near Buntingford, Hertfordshire, on August 20, 1906, in the 81st year of his age. His death has removed one who took a prominent part in the formation of the Mineralogical Society and who for the first ten years of its existence held the important office of Treasurer. He was compelled to relinquish this office in November 1885 by the continuance of the severe, and all but fatal illness which befell him in the summer of that year, and, as his health in the following year still remained precarious, he finally severed his connexion with the Society.

Among those who have assisted in the development of the mighty

industry which centres at Manchester, the Greg family hold an honoured place. One of the best known of its members was Robert Hyde Greg (1795–1875). A man of exceptional capacity and gifted with more than ordinary business acumen, he had a prosperous commercial career, and the high position he held among the merchants of Manchester was recognized by his election in 1844 to the presidency of the Chamber of Commerce. Despite the engrossing claims of his widely-ramifying business, he took keen interest in public affairs and still found leisure for antiquarian and scientific pursuits. He played a leading part in the agitation in favour of Parliamentary Reform and the Repeal of the Corn Laws, and his fellow-citizens testified to the esteem in which they held him by electing him in 1839 as their representative in Parliament, without his previous knowledge and even against his will, at a time when he was enjoying a brief holiday in Switzerland. He had sufficient appreciation of minerals to expend in 1835 the sum of £1,300 on the purchase of the fine collection which had been formed by Thomas Allan (1777–1833), F.R.S., a well-known banker in Edinburgh; but his knowledge of mineralogy was slight and he made no additions to the collection. He married in 1824 Mary (1799–1878), the daughter of Robert Philips, a prominent Manchester merchant, and had by her a family of four sons and two daughters. Their eldest child was Robert Philips Greg.

At the time of young Greg's birth the old order of things was on the eve of change, but had not entirely vanished: in Manchester, merchants still lived on the spot where their working hours were spent, and his parents were occupying a house in King Street actually adjoining his father's business premises in Chancery Lane. Two years later they moved to Ardwick, then in the country, but now an ugly suburb dominated by factory chimneys and penetrated by railway viaducts, and eventually at the end of 1831 they settled down at Norcliffe Hall, close to the Quarry Bank Mill, which has belonged to the Greg family since 1783. Norcliffe Hall is pleasantly situated near Wilmslow in Cheshire, and about ten miles from Manchester. Here Greg spent most of his boyhood. He received his early education from the Rev. John Colston, of Styal, thenceforth a lifelong friend; in 1840 he was sent to Mr. Malleson's School, Hove, Brighton, where he remained two years; and after spending a single session at the Manchester New College he proceeded in 1843 to Edinburgh University. At the age of nineteen he commenced his business training, and on his coming of age in 1847 he was taken into partnership by his father. He seems never

to have been completely absorbed in commercial affairs, and had certainly considerable leisure and opportunity for following up the many intellectual pursuits in which he was keenly interested. In 1857 he married Louisa Russell (1834–99), daughter of Samuel Stillman Gair, of Liverpool; they had no issue. They made their home first at Outwood Lodge, near Prestwich, and subsequently, in 1871, moved to Coles Park, which has been the property of the Greg family for upwards of 120 years. The house is charmingly placed amid sylvan surroundings, the natural beauties of which Greg did so much to enhance, and its approach recalls on a smaller and softened scale the features of a Derbyshire dale. Here they lived the remainder of their lives, and Greg engaged in the varied duties and occupations of a country gentleman. In 1873 he was appointed Justice of the Peace for the County, and in 1897 he succeeded to the Chairmanship of the Buntingford Bench. He enjoyed good health until his critical illness in 1885; he was affected by some form of blood-poisoning and had to suffer the amputation of his right foot, an operation which owing to the subsequent gangrening of the wound nearly cost him his life. Convalescence was tedious and slow, and two years elapsed before he recovered such measure of activity as an artificial substitute for his lost foot would allow. In 1895 his wife was attacked by the epidemic of influenza prevalent at that time, from which she never wholly recovered and to the after-effects of which she succumbed four years later. After her death Greg led a very quiet life; indeed, his own impaired health and the increasing weight of years would have in any case resulted in comparative seclusion. His death, though sudden, was not entirely unexpected. He was buried on August 23 at Westmill, of which village he was the squire, and the funeral was attended by a large number of relatives and others wishing to pay to him a last token of respect.

Until the time of his critical illness, Greg was an ardent collector; full of enthusiasm, he would spare no effort and grudge no expense to secure a coveted specimen. He began with spiders as a boy. On reaching manhood he turned his attention to the 'Allan' collection of minerals, then in his father's possession at Norcliffe Hall, and expended some £800 in the purchase of desirable specimens. Thanks to his energy, the collection became by far the finest private collection of minerals of the time in this country. The acquisition of specimens by purchase or exchange brought him into relations with collectors and others interested in minerals. In this way he made the acquaintance of W. G. Lettsom (d. 1887), like himself a keen collector, with whom he

collaborated in the production of the 'Manual of the Mineralogy of Great Britain and Ireland', which though published in 1858—nearly half a century ago—still remains the only work dealing with the general distribution of minerals in the British Isles. The book was written in four years, a remarkably short space of time for a work of that kind. With its publication Greg's interest in minerals seems to have waned, and in 1860, two years after its publication, he negotiated on behalf of his father the sale of the collection to the Trustees of the British Museum. He published a few papers on mineralogical subjects, the most important of which are the description of a new oxychloride of lead, matlockite, the discussions of the crystalline forms of leucophane and of rhodonite, and a paper with the late Professor Heddle on British pectolites. During the succeeding eighteen years he devoted much attention to the study of meteorites and meteor-showers, mainly from the astronomical point of view. He was a member of the Committee appointed by the British Association to report on observations of luminous meteors, and he wrote a large number of papers bearing on this subject, which form an enduring contribution to science. He got together a small collection of meteorites which was sold in 1865 to the Trustees of the Calcutta Museum for £500, and commenced in 1875 the formation of a collection of prehistoric implements which he sold in 1889 for £304. In consequence doubtless of the lengthy visit which he and his wife together with a party of relations paid to Egypt and the East in 1880, he commenced, three years later, a book on the comparative philology of the old and new worlds; it, however, did not actually appear till 1893, owing to the intervention of the severe illness already alluded to.

Besides being a member of the Mineralogical Society (1876–86), Greg belonged to the Royal Astronomical Society (1868–81), the Society of Antiquaries (1878–94), and the Geological Society (1853 till his death), and he frequently attended the meetings of the British Association. According to the Royal Society's Catalogue of Scientific Papers, Greg published twenty-six papers, and was joint author of two others, in addition to the two books mentioned above.

G. F. H. S.

John George Goodchild (1844–1906).

Mr. J. G. Goodchild, who died at Edinburgh on February 21, 1906, was an officer of the Geological Survey, to which he became attached in 1867. He was born near London on May 26, 1844. For many years

he was engaged in mapping part of the Lake District, and, although glacial geology occupied much of his attention while there, he became greatly interested in the local minerals and published 'Contributions towards a List of the Minerals occurring in Cumberland and Westmorland.' This paper appeared in the 'Transactions of the Cumberland and Westmorland Association' (1882–5), of which he was editor. Compelled by ill-health to abandon field-work, he was stationed for some years in the London office of the Survey, whence he was transferred to Edinburgh in 1887. There he took charge, first of the collections of the Scottish Survey, and afterwards of the mineral collection of the Royal Scottish Museum, formerly the 'Edinburgh Museum of Science and Art'. Under the influence of Dr. M. F. Heddle, whose collection passed officially into his charge, he became an enthusiastic student of the minerals of Scotland, and many papers, dealing especially with their probable genesis, proceeded from his active pen. He prepared, too, an excellent guide to the collections under his care, and on Heddle's death he undertook the editing of 'The Mineralogy of Scotland'. The manuscript required much labour in its preparation for press, and important additions, including many plates, were made by the editor. Mr. Goodchild was a man of extremely varied interests, giving at times serious attention to ornithology, botany, ethnology, and archaeology. He was a ready writer (being the author of some two hundred papers) and remarkably fluent as a speaker, so that he was induced to devote much time to lecturing, and in spite of long continued ill-health achieved in this direction pronounced success.

Vivant Léon Moissenet (1831–1906).

By the death of Professor Moissenet at Chaumont on February 2, 1906, the Society loses one of its earliest Honorary Members, he having been elected in 1877. He was born on August 2, 1831, at Chalon-sur-Saône. After passing through the courses of the Polytechnic School and the School of Mines in Paris, he became attached to the French Department of Mines, from which he retired in 1893 with the title of Honorary Inspector General of Mines. In 1869 he became Professor of Assaying and Analytical Chemistry in the School of Mines at Paris. In earlier years he paid several visits to the mining districts of England, and his first paper, in 1857, was on the deposits of lead-ore in the Carboniferous Limestone of Flintshire. In 1874 he published a pamphlet entitled 'Études sur les filons du Cornwall', which was translated into English by Mr. J. H. Collins in 1877.

Pierre Curie (1859–1906).

Professor Curie, the co-discoverer with his wife, Madame Sklodowska Curie, of the element radium, and also well known as a physicist, met his death as the result of a street accident in Paris on April 19. He was born in Paris on March 15, 1859, and received his early training at the Sorbonne, graduating as Doctor of Science in 1895. In the same year he became Professor of Physics in the Municipal School of Physics and Chemistry, and in 1900 Professor at the Sorbonne. Some of his earlier work, done in conjunction with his elder brother Jacques Curie, related to the piezoelectricity of crystals (1880); he also published papers on the symmetery of crystals (1884–5) and the capillarity constants of their faces (1885). Electrical researches occupied his attention until his work on radio-activity led to the discovery, in 1898, of radium in the mineral pitchblende. He was a life-member of the French Mineralogical Society.

Henry Augustus Ward (1834-1906).

Dr. Henry A. Ward, who, at the age of seventy-two, was knocked down and killed by a motor-car at Buffalo on July 4 last, was born at Rochester, New York, on March 9, 1834. After studying for four years at the School of Mines in Paris, he became, in 1859, Professor of Natural Science in the University of Rochester, a post which he held till 1865. For a time he acted as superintendent of gold mines in Montana and South Carolina, but soon afterwards returned to Rochester and founded the now well-known 'Ward's Natural Science Establishment', with which he was actively connected for over thirty years. Always an enthusiastic and energetic collector and distributor of specimens belonging to various branches of natural history, he in later years turned his attention largely to meteorites. He could tell many interesting tales of adventure which had befallen him during his travels in out-of-the-way places all the world over, undertaken with the object of securing examples of meteoric falls not represented in his collection. After disposing of large collections of meteorites to the Field Columbian Museum in Chicago and to Mr. C. S. Bement of Philadelphia, he commenced in 1894, at the age of sixty, the Ward-Coonley collection, which in the comparatively short space of ten years became one of the finest in existence. A detailed catalogue of this collection, together with a list of all known meteorites, was published by Professor Ward in 1904 ('Catalogue of the Ward-Coonley collection of Meteorites', Chicago, 1904, 4to, pp. xii +

113, with 10 pls.). At that time the collection, which is now exhibited in the American Museum of Natural History at New York, contained representatives of 603 meteoric falls, with a total weight of material of 2,495 kilograms. Professor Ward was the author of several papers on meteorites, and had collected a large amount of information relating to these bodies, on which he intended to publish a treatise.

REVIEW.

The Gem-cutter's Craft. By LEOPOLD CLAREMONT. Pp. xvi. + 296, small quarto; with 118 illustrations. (London: George Bell & Sons, 1906. Price 15*s.* net.)

The title of this book, together with the statement in the preface that it is perhaps the first work on precious stones that has been written by a practical gem-cutter, would lead us to expect full details and valuable hints concerning the work of the lapidary. In this, however, we are considerably disappointed, for the description of the modern methods of cutting precious stones occupies less than thirty pages, and of this a very large portion is taken up with illustrations, which though effective exhibit considerable sameness. What we do find are descriptions to the different kinds of precious stones, but these descriptions leave much to be desired.

Throughout the book there are numerous errors, errors not only in the mis-statement and hopeless confusion of principles, facts, and quantities, but also in spelling and grammar. To select only two examples: diamond is said to crystallize as a 'six-sided octahedron', and corundum as scalenohedra. Blunders of such a kind as these one expects to meet with only in the hurried answers to an examination paper; but when the author has presumably had the opportunity of referring to the books which he recommends to his readers, they are inexcusable. In this bibliography, by the way, we miss a mention of Professor Church's well-known Handbook.

The book is well illustrated, though the figures are scarcely referred to in the text. Some of the photographic reproductions of uncut specimens of gem-stones come out very successfully, whilst others would have been better omitted. The specimens represented are in the British Museum collection of minerals, and were photographed by Mr. T. C. Hepworth, whose notes could not have been referred to, since the statements of the relative sizes of the specimens and figures are invariably incorrect. The book is well printed and issued in an attractive form, and this is the most that can be said in its favour.

ABSTRACTS.

Die Skiodromen. Ein Hilfsmittel bei der Ableitung der Interferenzbilder. (F. Becke, Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1–34).[1]

Professor Becke has made a careful study of the conditions that determine the form and position of the shadows—bars or brushes—seen when sections of anisotropic crystals are examined in convergent light between crossed nicols, and shows how, by an examination of these phenomena, both the optical characters of the crystal and the position of the section can be approximately determined.

The principal optical directions are first considered as projected from the centre on to the surface of a sphere. About the points of emergence of the optic axes as foci two systems of confocal spherical ellipses[2] are drawn. One system has the acute bisectrix as centre, the other the obtuse bisectrix. The two systems cut each other at right angles and form a network covering the sphere. At any point of intersection the tangents to the curves are the directions of vibration of the two wave-fronts whose normals meet the sphere at that point.

The curves which have the acute bisectrix as centre are termed equatorial ellipses, and those with the obtuse bisectrix as centre, meridian ellipses. In uniaxial crystals the former are represented by circles having the points of emergence of the optic axis as centre, and the latter by the great circles passing through those points.

The ellipses of one system have the tangential vibrations faster than the normal vibrations and are referred to as α-ellipses. Those of the other system whose tangential vibrations are the slower are termed in same manner γ-ellipses. In positive crystals the α-ellipses are equatorial and the γ-ellipses meridian, while in negative crystals the reverse is the case.

In order to apply these principles to the investigation of the images afforded by sections of minerals in convergent polarized light, the sphere is projected orthogonally on to a plane which is parallel to the plane of the section, and therefore at right angles to the axis of the microscope.

[1] Compare this volume, p. 230.

[2] A spherical ellipse is a curve on the surface of a sphere which has the property that the sum of the angular distances of any point upon it from two foci on the sphere is constant.

The distance of each point on the plane of projection from the foot of the perpendicular through the centre of the sphere is proportional to the sine of the angular distance on the sphere, a relation that approximately holds good in the image seen in convergent light.

The projections of the ellipses are called skiodroms ('shadow-tracks'), and they may be distinguished as equatorial and meridian, or α- and γ-skiodroms, according to the characters of the ellipses from which they are projected. In the centre of the field of view they cut each other at right angles, but elsewhere they are oblique, and the obliquity increases with the distance from the centre. See figs. 1 and 2.

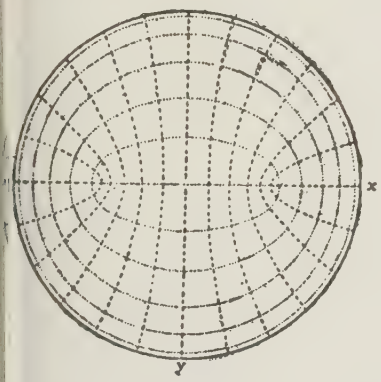


Fig. 1.

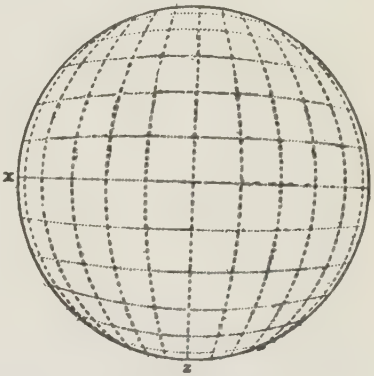


Fig. 2.

Fig. 1.—Skiodroms of a biaxial, negative crystal ($2V=60°$) projected on a plane at right angles to the acute bisectrix. The dotted lines are the equatorial skiodroms: the crystal being negative, these are γ-skiodroms, that is, their tangents are parallel to the vibrations of the wave-fronts with less velocity. The interrupted lines are the meridian skiodroms, which are here α-skiodroms.

Fig. 2.—The same projected on a plane parallel to the optic axial plane.

These figures first appeared in Denkschr. Akad. Wiss. Wien, 1904, vol. lxxv.

In any position of the section relatively to the nicols the vibrations that are parallel to those of either nicol are extinguished, and the curve of one or more branches uniting all the points where this is the case is called an isogyre. Near the centre of the field, where the skiodroms meet at right angles, the vibrations parallel to both systems of skiodroms are extinguished at the same points at the same time and the isogyre is represented by a distinct dark bar or curve; but near the periphery, where the skiodroms, and therefore the traces of the vibrations, are distinctly oblique to one another, the two vibrations at any point do not

extinguish simultaneously and the isogyre is represented by a diffused brush.

Professor Becke describes in detail the forms of the skiodroms and the resulting shadows or isogyres. Petrologists are already more or less familiar with the shape and movements of the latter when an axis of optical symmetry (a bisectrix or optic normal) or an optic axis is in the field of view, and there is little difficulty in recognizing the position of the section and the optical characters of the crystal. It will therefore only be necessary in this place to deal with sections which do not come under this heading, though the same principles are, of course, applicable to all sections, subject only to such obvious modifications as the special conditions of each case imply.

When the isogyre passes through the centre of the field it is termed a central isogyre. The vibrations in the centre of the field are then parallel to those of the nicols and the section is in the position of extinction in parallel polarized light.

When the normal to the section lies in a plane of optical symmetry, the central isogyre is straight and parallel to the direction of vibration of one of the nicols.

The normals to all oblique sections of uniaxial crystals lie in a plane of optical symmetry, and have therefore a straight central isogyre parallel to a nicol. On rotating the section, the isogyre moves laterally and, while remaining approximately parallel to its central position, shows a slight pendulous motion. The end of the isogyre nearer the optic axis moves round the circumference of the field in the same direction as the stage rotates and is termed by Professor Becke the homodrom end; the other extremity of the isogyre, which moves round the circumference in the opposite direction, he calls the antidrom end.

If the normal to a section of a biaxial crystal lie in the optic axial plane, the phenomena are similar to those of an oblique section of a uniaxial crystal, except that the pendulum motion of the isogyre is more pronounced and that the antidrom end moves faster than the homodrom end which is that nearer an optic axis. See fig. 2, p. 232 of this volume. If, on the other hand, the section-normal lie in a plane of optical symmetry passing through the optic normal, the homodrom end, which is directed to the bisectrix in the same plane of symmetry, moves faster than the antidrom end, and the movement of the whole isogyre resembles that of a fan. See fig. 5, on the same page.

If the normal to a section does not lie in a plane of symmetry, the central isogyre is usually curved, but its movements are similar to those

already described, varying in character according as the normal approximates to the optic axial plane or one of the other planes of symmetry.

In the case of most sections a distinction can be made between longitudinal skiodroms (Längs-Skiodromen) and transverse skiodroms (Quer-Skiodromen), the former showing less curvature than the latter within the limits of the field. The central isogyre either coincides with the central longitudinal skiodrom or makes with it an angle of less than 45°. In uniaxial crystals the longitudinal skiodroms are always meridian, while in biaxial crystals which are not neutral—that is, in which the optic axial angle is not exactly a right angle—they are meridian in the majority of cases, being equatorial in limited areas between the acute bisectrix and the optic axes and between the obtuse bisectrix and the optic normal. These areas diminish in size as the optic axial angle decreases.

The direction of vibration of the nicol, which either coincides with or more nearly approximates in direction to the central isogyre in the centre of the field, is parallel to the longitudinal skiodrom at that point. When this is the direction of the slower vibration, i. e. when the longitudinal skiodroms represent γ-ellipses, the section is said to have a positive reaction; when it is in the direction of the faster vibration the section has a negative reaction.

In uniaxial crystals the sign of the crystal is always that of the section; while in biaxial crystals this relation holds good more often than not, and its probability increases as the optic axial angle diminishes.

Professor Becke gives the following rule for determining the sign of the reaction of a section:—

Rotate the stage till the central isogyre is either parallel to the north and south cross-wire, or makes an angle of less than 45° with it, and has its homodrom end towards the north. Then insert a gypsum-plate with the direction of the α (fast) vibration north-west and south-east. If the colour fall to the east and rise to the west of the isogyre, the longitudinal skiodroms correspond to the γ-ellipses and the reaction of the section is positive [1]. If the colours rise to the east and fall to the west, the reaction will be negative.

[1] This result is due to the fact that the longitudinal skiodroms—which in a positive section are the directions of vibration of the slow waves—converge towards the north. In the centre of the field they are at 45° with the directions of vibration in the gypsum-plate and do not influence the colour; on the east they approximate in direction to the vibrations of the fast waves in the gypsum and compensation occurs; while on the west they approximate to the vibrations of the slow waves in the gypsum, and the relative retardation in the gypsum is increased.

A straight central isogyre which makes an angle of 45° with the vibrations of the nicols indicates a section whose normal lies in the plane including an optic axis and the optic normal of a crystal whose optic axial angle is a right angle. J. W. E.

Messung des Winkels der optischen Achsen aus der Hyperbelkrümmung. (F. Becke, Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 35–44.)

In this communication Professor Becke describes a graphic method of determining the optic axial angle of a crystal from the shape of the hyperbolic brushes or isogyres, when a section, examined in convergent polarized light, shows an optic axis in the field. The isogyre is traced in different positions by means of a camera-lucida and a rotating table connected mechanically with the rotating stage and turning with it. The latter mechanism is unnecessary with a microscope, the nicols of which rotate, and in the following brief description of the principle of the method it is assumed that such a microscope is employed.

The nicols are first rotated till the isogyre shows a straight line, the trace of the optic axial plane, through the optic axis parallel to the direction of vibration of one of the nicols. This is traced by means of the camera-lucida. The nicols are then rotated through 45°, and the hyperbolic curve now seen is traced on the same diagram. The point of intersection A_1 of the two tracings corresponds to the optic axis. The tracing of the optic axial plane and that of the optic axis A_1 and a point H on the hyperbola are then transferred to a stereographic projection. Each point to be transferred is determined in terms of its angular position (azimuth) and distance from the centre of the field in convergent polarized light. The former remains the same in the stereographic projection, and from the latter the angular distance and hence the distance in the stereographic projection can be easily obtained.

In the stereographic projection a great circle is drawn through the optic axis A_1 and the point H on the hyperbola. Through H a straight line HF is drawn parallel to the second position of one of the nicols and in the direction of the acute bisectrix. A great circle is then drawn through H making the angle A_2HF equal to the angle A_1HF, and the point A_2, where it meets the great circle representing the optic axial plane, will be the projection of the second optic axis. The length of the arc A_1A_2, which is equal to the acute optic axial angle, is then determined in the usual manner.

Professor Becke gives full details of the procedure to be followed. The results obtained are under favourable conditions correct within two degrees. J. W. E.

Ueber die dunklen Büschel von Dünnschliffen im convergenten Lichte. (H. Hilton, Zeits. Kryst. Min., 1906, vol. xlii, pp. 277–278.)

Mr. Hilton shows that in the study of the bars and brushes (isogyres) seen in convergent light and the determination of the optic axial angle of crystals by this means (see preceding abstract), the gnomonic projection may be employed for the representation of points which are not too far removed from the centre of the field. He states that if ρ be the radius of the sphere, and if in the gnomonic projection the axes of X and Y be parallel to the directions of vibration of the nicols, and x_1y_1 and x_2y_2 be the projections of the optic axes, then the equations of the partial isogyres, which are the loci of the points where the tangents of the projections of the spherical ellipses are parallel to the axes of X and Y respectively, will be the following :—

$$x\{(y^2-\rho^2)(y_1+y_2)+2y(\rho^2-y_1y_2)\}=(y^2+\rho^2)\{y(x_1+x_2)-(x_1y_2+x_2y_1)\}$$

and

$$y\{(x^2-\rho^2)(x_1+x_2)+2x(\rho^2-x_1x_2)\}=(x^2+\rho^2)\{x(y_1+y_2)-(x_1y_2+x_2y_1)\}.$$

J. W. E.

The Isomorphism and Thermal Properties of the Feldspars. A. L. Day and E. T. Allen. Preliminary notice: Amer. Journ. Sci., 1905, ser. 4, vol. xix, pp. 93–142. Full account, with introduction by G. F. Becker, and optical study by J. P. Iddings: Carnegie Institution, Washington, publication No. 31, 1905, 95 pp., 26 plates; translation in Zeits. physik. Chem., 1905, vol. lix, pp. 1–54, 7 plates. (Abstract in Nature, 1905, vol. lxxii, p. 258).

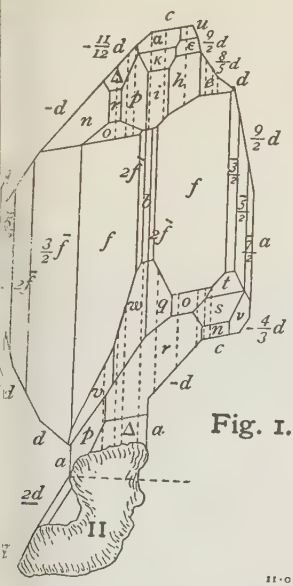
On Wollastonite and Pseudo-Wollastonite,—Polymorphic forms of Calcium Metasilicate. E. T. Allen and W. P. White, with optical study by F. E. Wright. Amer. Journ. Sci., 1906, ser. 4, vol. xxi, pp. 89–108.

The Lime-Silica Series of Minerals. A. L. Day and E. S. Shepherd, with optical study by F. E. Wright. Ibid., 1906, vol. xxii, pp. 265–302; and Journ. Amer. Chem. Soc., 1906, xxviii, pp. 1089–1114.

Minerals of the Composition $MgSiO_3$; a Case of Tetramorphism. E. T. Allen, F. E. Wright, and J. K. Clement. Ibid., 1906, vol. xxii, pp. 385–438.

The papers, of which the titles are quoted above, give the results so far published of a remarkable series of researches now being carried out in the Geophysical Laboratory of the recently founded Carnegie Insti-

tution of Washington. They have for their aim the preparation of the various rock-forming minerals in a pure and crystallized condition, and the determination, as far as possible, of all their physical properties (thermal, optical, specific gravity, &c.), their conditions of formation and alteration, and the relations of the different polymorphic forms to each other. The large number of experiments are performed in an electric furnace which can be regulated with delicacy up to temperatures of 1,600°C.; the observations are plotted on curves and discussed from a physico-chemical standpoint. Many important results have already been obtained and some interesting deductions bearing on petrology have been drawn.



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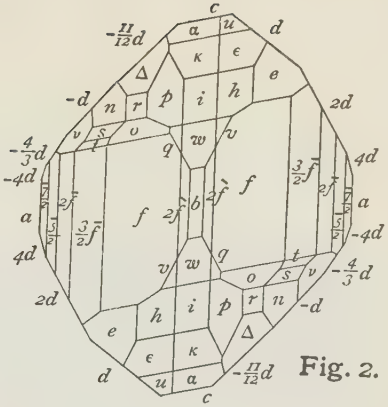

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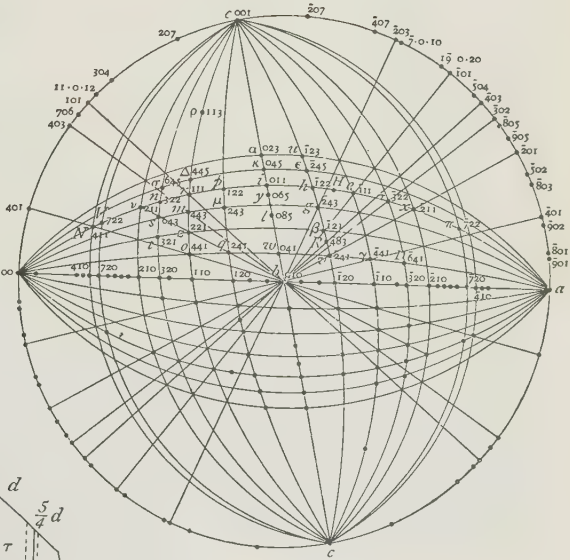

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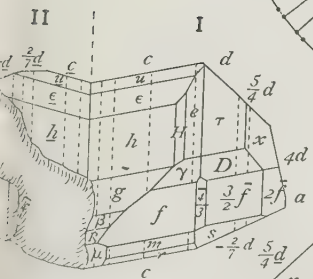

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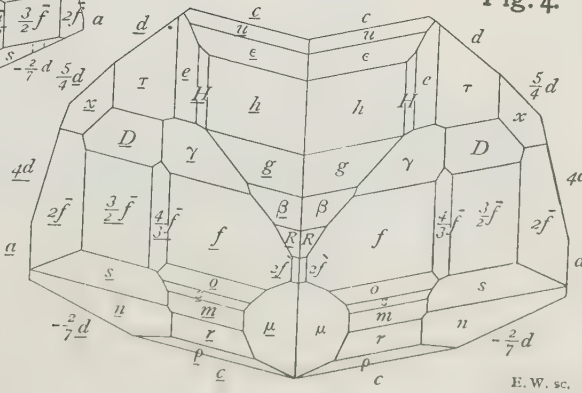
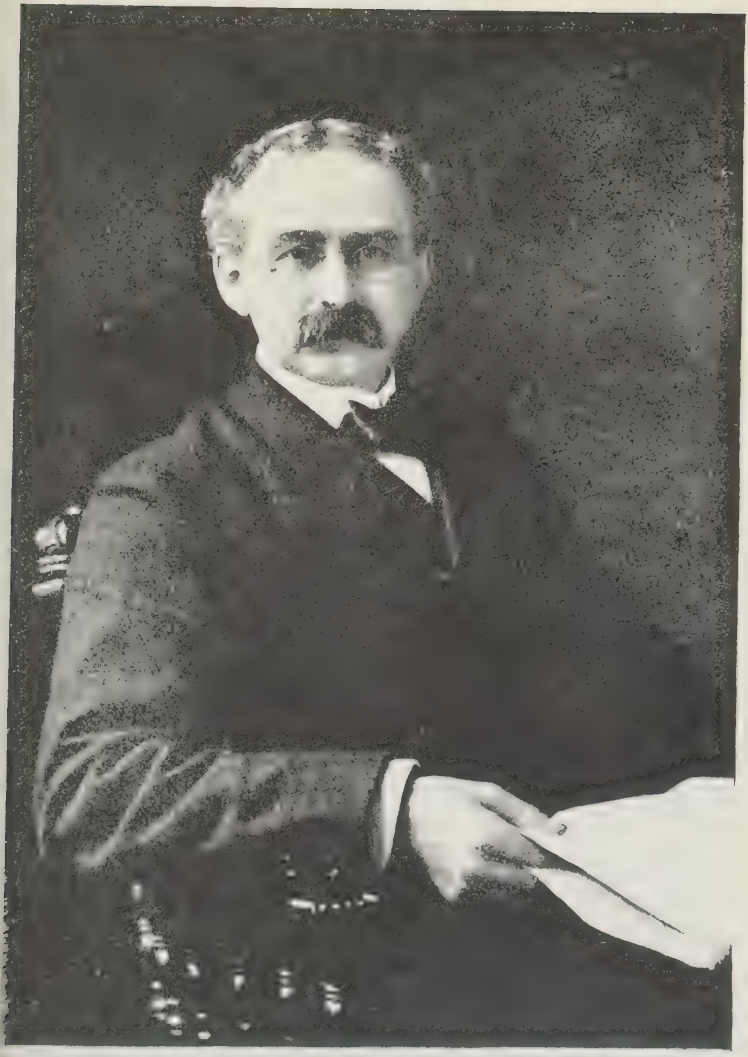


Fig. 4.

E. W. sc.



Samuel Lewis Penfield.

At the age of 46.)

Robert Philips Greg.
(At the age of 79.)

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